AD-A060 301 RESEARCH TRIANGLE INST RESEARCH TRIANGLE PARK N C APP--ETC F/G 18/6

STUDY OF CRISIS UTILIZATION OF SMALL SHELTER SPACE.(U)

AUG 78 S B YORK, J S MCKNIGHT DCPA01-77-C-0232

UNCLASSIFIED RTI/1533/00-05F NL

1 OF 2

ADA

060301

AD A060301

DDC FILE COPY

UNIT

OF SMALL SHELTER SPACE

LEVEL II

12

August 1978

DCPA Work Unit 1217F

Contract No. DCPA 01-77-C-0232

FINAL REPORT RTI/1533/00-05 F

STUDY OF CRISIS UTILIZATION OF SMALL SHELTER SPACE

Approved for Public Release; Distribution Unlimited

RESEARCH TRIANGLE INSTITUTE
Post Office Box 12194
Research Triangle Park, North Carolina 27709

78 10 17 026

RESEARCH TRIANGLE INSTITUTE
OPERATIONS ANALYSIS DIVISION
APPLIED ECOLOGY DEPARTMENT
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

DCPA Review Notice

This report has been reviewed by the Defense Civil Preparedness Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Defense Civil Preparedness Agency

DETACHABLE SUMMARY

FINAL REPORT RTI/1533/00-05F

August 1978

Study of Crisis Utilization of Small Shelter Space

by

S. B. York, III and J. S. McKnight

for

DEFENSE CIVIL PREPAREDNESS AGENCY
Washington, D.C. 20301

under

Contract No. DCPA01-77-C-0232
DCPA Work Unit 1217F

Approved for Public Release; Distribution Unlimited

facilities. This particularly affects the provision of ventilation. It appears that most buildings have existing water supply systems, regardless of size, however, small facilities are more likely to be served by wells. Small facilities are also more likely to contain a sufficient number of commodes, but have a smaller chance than large facilities of containing emergency generators.

III. Description of Options for Providing Services

A step-wise procedure is used in developing a description of options for providing each of the following services: lighting, ventilation, water supply, sewage disposal, and solid waste disposal. In each case, guidelines are developed upon which to base minimum service requirements, these required levels of service are compared to estimated existing services, and finally, methods of achieving the required upgrading are defined.

It is assumed that artificial lighting systems are adequate and are already in place. Therefore, guidelines are presented for connecting engine-generators to the existing circuits. Expedient means of providing lighting also are listed to be used if emergency generators are not available or if the building contains no artificial lighting system.

In the ventilation section, it is submitted that most small buildings do not contain mechanical ventilation systems that are adequate for shelter use. Recommendations are made for providing forced ventilation in buildings with inadequate or no mechanical ventilation systems. The guidelines for connecting engine-generators to existing circuits apply to existing ventilation systems as well as to lighting systems.

The water supply requirement is related to ventilation rate, outside temperature, and humidity to guide the determination of the quantity of water that should be provided and to demonstrate the interrelationships of the various life-support systems. Methods of providing water in shelters are proposed and means of achieving and maintaining the necessary purity of water are outlined.

Factors are presented that should be considered in determining the amount of sewage that must be handled by the sewage disposal system. Alternative expedient methods for the sanitary disposal of sewage are presented along with recommendations on determining the type of disposal facilities to implement.

SUMMARY

I. Introduction and Objectives

Under the concept of crisis relocation planning (CRP), during a period of escalating international tensions that have the implication of leading to a nuclear war, people from high-risk areas such as metropolitan communities will be evacuated to outlying rural host areas that have a low risk of receiving direct weapons effects. A major consideration in the development of crisis-relocation plans is the provision of fallout shelter protection for the relocated populations. One option that could provide much of the needed shelter space is the use of small facilities, such as local stores, churches, and schools. Previously completed research sponsored by DCPA has identified means of improving fallout protection in such facilities. Also, a recently completed RTI study investigated the options available for providing lighting, ventilation, water, and sanitary waste disposal in large facilities capable of housing groups of more than 1,000 people. This study addresses the provision of the above life-support services for groups of people housed in small facilities. Alternatives are defined for providing these services, the relationships of group size and occupant density to the provision of services are examined and examples of the planning required to implement these systems are developed.

II. Definition of Facility Characteristics

In this section, building characteristics that are pertinent to the provision of services are identifid. Buildings are categorized according to use into one of nine use classes defined by DCPA. The emphasis is on distinguishing relevant differences between small and large facilities, therefore, the same building codes and Host Area Facilities survey results that were employed in the large facility study [Ref. S-1] are used to establish typical values or ranges for existing services in each use class. These data give an indication of the services most likely to require upgrading and of the degree of upgrading that might be required.

The comparison of large and small facility characteristics shows that the building distribution varies greatly between large and small shelter

The solid waste disposal section describes the composition of solid waste and suggests a range of production rates to be used for planning purposes. Several options for the disposal of solid waste are presented.

IV. Relationships of Group Size and Occupant Density to the Provision of Services

Guidelines are developed to aid the local planner in determining the best method to effectively utilize the shelter resources in a particular host area. If a choice must be made between using large or small facilities, large facilities are generally favored unless potable water supply or waste disposal are severe problems due to shortages of water, storage containers, commodes, chemical toilets, collection containers, or disinfectants. Decreases in population density might be desirable in facilities with inadequate existing water supply or sewage disposal systems. Occupant density should not be increased until each facility is evaluated to ensure that the extra space requirements for water and waste storage do not conflict with the usable floor area needed for the shelter occupants.

V. Conclusions

In estimating the existing services in buildings and in describing options for providing or augmenting these services, RTI found that existing survey data are inadequate. Additional types of information that would be helpful to local planners are enumerated. Also, the interrelationships between the different systems in a facility are emphasized to ensure that the systems will be compatible.

VI. References

S-1. Wright, M. D., S. B. York, III, R. H. Hill, and J. L. McKnight, Study of Crisis Utilization of Large Shelter Space. Final Report 44U-1340. Research Triangle Institute, Research Triangle Park, North Carolina. August 1977.

9 Final rept. Oct 77-Aug 78

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 RTI/1533/00-05F	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 STUDY OF CRISIS UTILIZATION OF SMALL SHELTER SPACE.		5. TYPE OF REPORT & PERIOD COVERED Final: October 1977-August 1978 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 S. B. York, III J. S. McKnight		8. CONTRACT OR GRANT NUMBER(s) DCPA Contract No. 15 DCPA01-77-C-0232
9. PERFORMING ORGANIZATION NAME AND ADDRESS Research Triangle Institute P. O. Box 12194 Research Triangle Park, N. C. 27709		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Work Unit 1217F
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Civil Preparedness Agency Washington, D.C. 20301		12. REPORT DATE 11 Aug[redacted]978 13. NUMBER OF PAGES 102
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 111p.		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Crisis Relocation
Small Shelter Facilities
Host Areas

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study consisted of an investigation into the options available for utilizing small facilities such as local stores, churches, and schools for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary waste disposal systems for small groups of people. The emphasis of this study was on identifying differences in the characteristics of small facilities versus large facilities

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

409 702

20. Abstract (Continued)

and determining the influence of these differences on the provision of services. In describing methods for augmenting and/or providing services, the interrelationships among the different systems in a facility were analyzed.

Also, an investigation was made of the relationships of group size and occupant density to the provision of services. Factors relating to the effects of group size and occupant density were examined and presented as an aid to the local planner in developing the shelter plan for a particular host area.

All of the analyses were made using existing data already collected.

Example problems illustrating the planning required to implement life-support systems are included as an appendix.

RESEARCH TRIANGLE INSTITUTE
OPERATIONS ANALYSIS DIVISION
APPLIED ECOLOGY DEPARTMENT
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27709

FINAL REPORT RTI/1533/00-05F

August 1978

Study of Crisis Utilization of Small Shelter Space

by

S. B. York, III and J. S. McKnight

for

DEFENSE CIVIL PREPAREDNESS AGENCY
Washington, D.C. 20301

under

Contract No. DCPA01-77-C-0232
DCPA Work Unit 1217F

ABSTRACT

This study consisted of an investigation into the options available for utilizing small facilities such as local stores, churches, and schools for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary waste disposal systems for small groups of people. The emphasis of this study was on identifying differences in the characteristics of small facilities versus large facilities and determining the influence of these differences on the provision of services. In describing methods for augmenting and/or providing services, the interrelationships among the different systems in a facility were analyzed.

Also, an investigation was made of the relationships of group size and occupant density to the provision of services. Factors relating to the effects of group size and occupant density were examined and presented as an aid to the local planner in developing the shelter plan for a particular host area.

All of the analyses were made using existing data already collected.

Example problems illustrating the planning required to implement life-support systems are included as an appendix.

PREFACE

This study is the second part of a two part study into the provision of lighting, ventilation, potable water supply and waste disposal systems in existing facilities. The first part of this study is entitled Study of Crisis Utilization of Large Shelter Space and was performed by RTI under DCPA Work Unit 1217E, Contract No. DCPA 01-76-C-0318. The reports follow the same format and should be used together as several applicable tables in the large shelter study are referenced herein. In some instances, relevant sections of text from the large shelter study also are included.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

One of the options available to civil defense planners in the event of an international crisis that has the possibility of ending in a nuclear war is the relocation of the population at risk under the concept of Crisis Relocation Planning (CRP). Under CRP, the residents of areas likely to receive direct weapons effects are evacuated to outlying host areas with a lower risk of receiving these effects. Though out of the range of the thermal radiation and fire effects, evacuees would still be subject to the effects of radioactive fallout resulting from a nuclear explosion. Without adequate shelter protection, a large fraction of the population could receive lethal doses of radiation. Therefore, a major consideration in the development of crisis-relocation plans is the provision of fallout shelter protection in the host areas.

Most of the host (or reception) areas to which the population of high-risk areas would be relocated are sparsely populated small towns and rural communities. Consequently, only a limited number of fallout shelter spaces identified in the National Shelter Survey (NSS) are located in these areas. Therefore, it is necessary to identify alternate options for the provision of shelter. One option that could provide much of the needed shelter space is the use of small facilities, such as local stores, churches, and schools.

Means of upgrading fallout protection in such facilities have been developed under previously completed research sponsored by DCPA. Also, a recently completed RTI study investigated the options available for providing lighting, ventilation, water, and sanitary waste disposal in large facilities such as tunnels, government installations, and large industrial buildings. However, the methods of providing these life-support services to people housed in small facilities have not been addressed in previous studies. It is to the investigation of options available for providing these needed services for groups of less than 1,000 people that this study is aimed.

II. OBJECTIVES AND SCOPE

This study investigates the feasibility of crisis-implemented lighting, ventilation, water, sewage, and solid waste handling systems in small facilities. Also, the effects of group size and population density on the provision of services are evaluated. In addition, example plans for providing the needed services to several small facilities are presented as a guide to host area planners.

The steps in evaluating the feasibility of providing services to small facilities are to identify information about pertinent building characteristics, to estimate existing services from this information, and to describe methods of complementing existing services. In identifying pertinent building characteristics, the emphasis is on distinguishing relevant differences between small and large facilities. The effect of these differences on the provision of services is then described. Each of these steps is addressed in the following sections of this report.

III. DEFINITION OF FACILITY CHARACTERISTICS

This study is concerned with small facilities (buildings capable of housing no more than 1,000 people) in host areas. As was done previously by RTI in the Study of Crisis Utilization of Large Shelter Space [Ref. 1], buildings are categorized according to their use on the basis of nine use classes developed by DCPA. Table 1 shows the types of buildings that are included in each use class. Defining facility characteristics by use class enables the local planner to estimate the existing services available in a particular host area, if the numbers and sizes of facilities in each use class are known. The facility characteristics most relevant to the provision of lighting, ventilation, water supply and waste disposal systems include: existing lights, exterior wall apertures, mechanical ventilation systems, plumbing fixtures, and water supply.

Under the CRP concept, host area facilities are of two types, and the provision of services is significantly different for each type. Facilities which receive and house evacuees in the period of time prior to a nuclear attack are congregate care facilities. Spaces are allocated in these buildings on the basis of 40 square feet per person. Facilities providing (or upgraded to provide) protection from radioactive fallout are shelter facilities. Only 10 square feet per person are allocated in these facilities. Of course, many buildings can serve as both types of shelter. In such a building, sufficient services must be provided to support the people who would be housed during its use as a fallout shelter.

A. Fallout Shelter Facilities

In conducting the Study of Crisis Utilization of Large Shelter Space study, hereafter referred to as the large shelter space study [Ref. 1], RTI used building codes to estimate lighting and ventilation characteristics of existing buildings. The codes consulted were found to be sufficiently detailed and consistent in stipulating lighting and ventilation requirements to be used as a basis for estimating existing lighting and ventilation services in buildings. RTI consulted the following building codes: The National Building Code 1976, The Standard Building Code, The Building Code of the City of New York, and the Official Building Code of the City of Detroit [Refs. 2,3,4, and 5].

Table 1. Types of Buildings Included Under Each Use Class

Building Use	Use Class	Types of Buildings
Residential	10	Apartments/hotels Dormitories/barracks Row houses and duplexes
Educational	20	Kindergartens/elementary schools Junior high/high/preparatory schools Colleges/universities Business/professional/industrial schools Correctional schools Libraries/museums
Religious	30	Churches/synagogues Retreats/monasteries/convents
Government and Public Services	40	Hospitals Clinics Utilities Communication facilities Offices Jails/prisons/correctional institutions Armories/monuments/memorials
Commercial	50	Offices Food stores Stores other than food stores Warehouses Banks/financial institutions
Industrial	60	Factories/plants/manufacturing centers Food processing plants
Amusement/Meeting	70	Theatres/auditoriums Community centers
Transportation	80	Railroad stations/terminals Bus stations/terminals Airport terminals Airport hangers Marine terminals Automotive repair and storage stations
Miscellaneous	99	Categories not covered above

Table 2 presents the lighting requirements of the above building codes by use class. Included in this table are the window area requirements for natural light and some artificial light requirements. No qualifications are included pertaining to building size; therefore, these requirements can be applied in estimating existing lighting in small buildings. Similarly, Table 3 displays the ventilation requirements of the above building codes by use class. Aggregate openable window areas are stipulated for natural ventilation and minimum volumes of mechanical ventilation also are given, again with no qualifications pertaining to building size.

Building code requirements for plumbing, water supply and sewage disposal are neither sufficiently detailed nor consistent between codes to provide a basis for the estimation of existing building characteristics. However, the CRP Host Areas Facility Listing, maintained by DCPA, contains information on use, number of congregate care and shelter spaces, type of water supply, number of commodes, and other pertinent features for each facility surveyed. Therefore, in the large shelter space study, estimates of existing water supply and sewage disposal services were based on data from this listing. These data were also used to give an indication of the distribution of buildings by use class. Four counties representative of different geographic regions of the United States were chosen from the listing. The four counties selected for the analysis were Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; and Yuma County, Arizona.

Since the emphasis at this stage of the study was to distinguish relevant differences in building characteristics between small and large facilities, the same four counties were used as a basis for estimating existing water supply and sewage disposal services in small facilities. The data can be compared to the large shelter data to aid in identifying factors that result in modifications of the methods for providing services in large shelters to appropriate methods for providing services in small shelters.

Table 4 presents a summary of the data for small facilities (i.e., buildings with fewer than 1,000 shelter spaces) from the four counties as they were extracted from the listing. A total of 1627 facilities are included in the summary data, containing 427,827 shelter spaces. Over 50 percent of the facilities and almost 44 percent of the spaces are in the commercial use class. The next most prevalent use classes in terms of

Table 2. Lighting Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Light	Artificial Light 1/,2/
National 3/	Residential	10	Habitable rooms shall have 1 or more windows of area not less than 10 percent of the floor area served.	
	Educational Commercial Industrial	20 50 60	Such rooms shall have windows of area not less than 10 percent of the floor area served providing adequate illumination levels as established...4/,	or artificial lighting providing adequate illumination levels as established...4/
	Government and Public Services	40	Habitable rooms shall have 1 or more windows of area not less than 10 percent of the floor area served,	or artificial lighting providing illumination of not less than 30 foot candles at 2-1/2 feet above the floor.
	Religious Amusement/ Meeting Transportation	30 70 80	Such rooms and spaces shall have windows of area not less than 10 percent of the floor area served,	or artificial lighting.
Standard 5/	Habitable room	10-80	Habitable rooms shall have 1 or more windows with glazed openings of clear glass of area not less than 1/10 of the floor area of the room served,	or artificial lighting not less than 50 foot candles.
New York 6/	Occupiable room	10-80	Sources shall have an aggregate transmitting area of at least 10 percent of the floor area of the room or spaces served.	Adequate means for producing artificial light unless rooms or spaces occupied only during daylight hours and are provided with natural light.

(Continued)

Table 2. Lighting Requirements of Selected Building Codes (Continued)

Building Code	Building Use	Use Class	Natural Light	Artificial Light 1/,2/
Detroit 7/	Occupiable room	10-80	Windows shall have an aggregate area not less than 1/10 the floor area served,	or adequate means for producing artificial light.

1/ If the building code makes no provision for artificial light, then no entry is made in the table.
2/ If the building code calls for either natural or artificial light, then the entry under artificial light begins with "or":.
3/ Ref 2.
4/ Adequate illumination for educational, commercial, or industrial uses is more than adequate for shelter use.
5/ Ref. 3.
6/ Ref. 4.
7/ Ref. 5.

Table 3. Ventilation Requirements of Selected Building Codes

Building Code	Building Use	Use Class	Natural Ventilation	Mechanical Ventilation 1/,2/,3/
National 4/	Residential	10	Habitable rooms shall have 1 or more windows of aggregate openable area not less than 1/20th the floor area served.	
	Educational	20	Such rooms and spaces shall be provided with windows and/or skylights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing a minimum rate of 6 air changes per hour.
	Religious Amusement/ Meeting	30 70	Such rooms and spaces shall be provided with windows and/or skylights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing from 5 to 15 cfm of outside air per 10 sq. ft.
	Government and Public Services	40	Habitable rooms shall have 1 or more windows of aggregate openable area not less than 1/20th the floor area served,	or in residential restrained care facilities or penal institutions, provisions for not less than 7 air changes per hour and in office buildings 2.5 to 4 cfm of outside air per 10 sq. ft.
	Commercial	50	Such rooms and spaces shall be provided with windows and/or skylights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation providing from .5 cfm to 3.3 cfm of outside air per 10 sq. ft. in stores and 2.5 to 4 cfm of outside air per 10 sq. ft. in office buildings.

(Continued)

Table 3. Ventilation Requirements of Selected Building Codes (Continued)

Building Code	Building Use	Use Class	Natural Ventilation	Mechanical Ventilation 1/,2/,3/
	Industrial	60	Such rooms and spaces shall be provided with windows and/or sky-lights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation pro-viding typically from 15 to 30 cfm of outside air per 10 sq. ft.
	Transportation	80	Such rooms and spaces shall be provided with windows and/or sky-lights of aggregate openable area not less than 1/20th the floor area served,	or approved means of mechanical ventilation pro-viding at least 7.5 cfm of outside air per 10 sq. ft. in garages and 15 to 30 air changes per hour in tunnels.
Standard 5/	Habitable room	10-80	Habitable rooms shall have 1 or more windows that when fully opened shall provide an open area not less than 1/20th the floor area served,	or fresh air in sufficient quantity to maintain health-ful conditions as required by State laws or at least equivalent to the required natural ventilation.
New York 6/	Occupiable room	10-80	Such rooms shall have ventilating openings of area at least 5 percent the floor area being served,	or means of pro-viding from 3.3 to 25 cfm of outdoor air per 10 sq. ft.
Detroit 7/	Residential Commercial	10 50	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of pro-viding at least 2.5 cfm of outdoor air per 10 sq. ft.

(Continued)

Table 3. Ventilation Requirements of Selected Building Codes (Continued)

Building Code	Building Use	Use Class	Natural Ventilation	Mechanical Ventilation 1/,2/,3/
	Educational Religious Amusement/ Meeting	20 30 70	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 3.75 cfm of outdoor air per 10 sq. ft.
	Government and Public Services	40	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 3.75 cfm of outdoor air per 10 sq. ft. to hospitals and 12.5 cfm of outdoor air per 10 sq. ft. to offices.
	Industrial	60	Occupiable rooms shall be provided with windows having aggregate openable area not less than 1/20th the floor area served,	or means of providing at least 5 cfm of outdoor air per 10 sq. ft.
	Transportation	80	Every room or space above grade shall be provided with openings having an area not less than 2 percent of the floor area,	or shall be equipped with the equivalent mechanical ventilation. Below grade space shall be equipped with mechanical ventilation adequate to provide 6 air changes per hour.

1/ If the building code makes no provision for mechanical ventilation, then no entry is made in the table.
2/ If the building code calls for either natural or mechanical ventilation, then the entry under mechanical ventilation begins with "or".
3/ Mechanical ventilation values given for the National Building Code come from Ref. 6.
4/ Ref. 2.
5/ Ref. 3.
6/ Ref. 4.
7/ Ref. 5.

Table 4. Four-County 1/ Summary of Small Shelter Facility Characteristics 2/

Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Shelter Spaces	Percent of Total Spaces	Number of Facilities with Basements	Percent of Use Class with Basements	Number of Basement Spaces	Percent of Spaces in Use Class
Residential	10	145	8.9	46,836	10.9	2	1.4	640	1.4
Educational	20	177	10.9	64,778	15.1	19	10.7	6,888	10.6
Religious	30	101	6.2	27,420	6.4	30	29.7	6,307	23.0
Government and Public Services	40	179	11.0	53,217	12.4	33	18.4	8,905	16.7
Commercial	50	817	50.2	187,679	43.9	68	8.3	9,756	5.2
Industrial	60	26	1.6	8,546	2.0	8	30.8	1,944	22.7
Amusement/ Meeting	70	43	2.6	12,280	2.9	9	20.9	1,659	13.5
Transportation	80	136	8.4	26,449	6.2	2	1.5	81	0.3
Miscellaneous	99	3	.2	622	.1	0	0.0	0	0.0
TOTAL		1,627	100.0	427,827	99.9 5/	171	10.5	36,180	8.5

(Continued)

Table 4. Four-County [1] Summary of Small Shelter Facility Characteristics [2] (Continued)

Building Use	Water Supply							
	Facilities with Water Supply	Percent of Use Class with Water	Spaces with Water Supply	Percent of Spaces in Use Class with Water Supply	Facilities with Wells	Percent of Facilities in Use Class with Wells	Spaces Served by Wells	Percent of Spaces in Use Class Served by Wells
Residential	144	99.3	46,766	99.9	30	20.7	5,990	12.8
Educational	163	92.1	61,782	95.4	38	21.5	15,227	23.5
Religious	97	96.0	26,962	98.3	21	20.8	3,491	12.7
Government and Public Services	173	96.6	51,744	97.2	26	14.5	5,633	10.6
Commercial	798	97.7	184,647	98.4	107	13.1	21,108	11.2
Industrial	25	96.2	8,503	99.5	16	61.5	4,821	56.4
Amusement/ Meeting	42	97.7	12,235	99.6	18	41.9	2,685	21.9
Transportation	121	89.0	21,877	82.7	15	11.0	3,082	11.7
Miscellaneous	3	100.0	622	100.0	0	0.0	0	0.0
TOTAL	1,566	96.3	415,138	97.0	271	16.7	62,037	14.5

(Continued)

Table 4. Four-County 1/ Summary of Small Shelter Facility Characteristics 2/ (Continued)

	Commodes					Generators	
Building Use	Existing Commodes	Facilities with Sufficient Number of Commodes 3/	Percent of Use Class with Sufficient Number of Commodes	Additional Commodes Needed 4/	Deficit of Commodes per 1,000 People	Number of Facilities with Generator	Percent of Facilities in Use Class with Generator
Residential	1,543	117	80.7	75	1.6	0	0.0
Educational	763	30	16.9	764	11.8	0	0.0
Religious	275	16	15.8	328	12.0	0	0.0
Government and Public Services	626	32	17.9	588	11.0	15	8.4
Commercial	1,783	153	18.7	2,463	13.1	2	0.2
Industrial	56	3	11.5	109	12.8	0	0.0
Amusement/ Meeting	125	8	18.6	139	11.3	0	0.0
Transportation	214	42	30.9	381	14.4	0	0.0
Miscellaneous	17	2	66.7	3	4.8	0	0.0
TOTAL	5,402	403	24.8	4,850	11.3	17	1.0

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Small facilities are those facilities listed on the CRP (Crisis Relocation Planning) Host Areas Facility Listing from 4 arbitrarily selected U.S. counties that have less than 1,000 shelter spaces.
3/ Based on a minimum requirement of 1 commode per 50 shelter spaces.
4/ Commodes needed to bring facilities with fewer than the minimum requirement for commodes up to the minimum number required.
5/ Percentages do not total 100 percent due to rounding.

facilities and shelter spaces are government and public services and educational. Next to miscellaneous facilities (all three buildings in this category are funeral homes), the least prevalent use class is industrial. There are basements in 10.5 percent of the small facilities in the four-county sample, with 8.5 percent of the spaces in basements. This is significant to the upgrading of fallout protection, but it does not affect the provision of services considered herein.

Further examination of the data in Table 4 shows that 96.3 percent of the facilities have existing water supplies, though only 16.7 percent of the facilities and 14.5 percent of the spaces are served by wells. Facilities with wells are fairly evenly distributed among all of the use classes. Although a relatively high percentage of facilities in the industrial and amusement/meeting use classes are served by wells, the total number of spaces served by wells in these two use classes is only 7,506. It appears that only in the residential use class (where 80.7 percent of the facilities have a sufficient number of commodes for shelter use) is there a good likelihood of finding existing sewage disposal systems that do not need upgrading. Generators are found in only two use classes, government and public services and commercial, and only the former use class has a significant number of facilities (15) with generators. However, most of these facilities are water pump stations, municipal government buildings, fire stations, etc., and they will not be available as shelter for the general public in a crisis situation. Therefore, it seems that a negligible number of small facilities will be equipped with emergency generators on site.

B. Congregate Care Facilities

The major difference between a congregate care and a fallout shelter facility affecting the provision of services is the greater population density (by a factor of 4) housed in the fallout shelter facility. Therefore, the information contained in Table 2 (concerning the lighting requirements of the building codes) and in Table 3 (concerning the ventilation requirements of the building codes) is directly applicable to congregate care buildings, with one modification: the minimum requirement for mechanical ventilation stipulated in Table 3 in terms of cubic feet per minute (cfm) per 10 square feet should be multiplied by 4 to yield the rate in terms of cfm per 40 square feet (the floor area allocated per congregate care space).

Table 5 presents information on congregate care facilities for the four-county sample from the CRP Host Areas Facility Listing. Table 5 represents 2,268 congregate care facilities (39 percent more congregate care facilities than fallout shelter facilities) containing 245,151 spaces (43 percent fewer congregate care spaces than fallout shelter spaces). The greater number of congregate care facilities is because many facilities with congregate care spaces were determined to have no upgradable fallout shelter space. On the other hand, there are fewer congregate care spaces because of the smaller population density in congregate care facilities. The difference in population density also explains the relatively large number of congregate care facilities with sufficient numbers of commodes and the relatively fewer number of commodes needed per 1,000 people. The water supply and generator data are very similar for the two classifications of shelter.

C. Comparison of Large and Small Facility Characteristics

As has already been noted, the building code data upon which estimates of existing lighting and ventilation are based does not differentiate between building sizes. Therefore, the building code requirements for natural light, artificial light, natural ventilation, and mechanical ventilation are equally as applicable in estimating existing lighting and ventilation systems in small facilities as they are in large facilities. The differences in upgrading small facilities versus large facilities are due to the differences in the types of existing circuits or in the capacities of the systems required. These factors will be examined in the next section, "Description of Options for Providing Services."

Table 6 presents a comparison of four-county large and small shelter facility characteristics. The data in this table are used to identify differences in building distribution by use class, existing water supply, number of commodes, and number of generators. Note that, although there are nine times as many small shelter facilities as large, almost 138,000 more spaces (or 32.2 percent more) are identified in large shelter facilities than in the small shelter facilities. The relative number of spaces in large versus small shelter facilities is an important factor to consider when preparing contingency plans for particular host areas. This will be developed further in the section on "The Relationships of Group Size and Occupant Density on the Provision of Services." Table 6 shows that the

Table 5. Four-County [1/] Summary of Small Congregate Care Facility Characteristics [2/]

Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Congregate Care Spaces	Percent of Total Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Use Class with Water	Water Supply: Spaces with Water Supply	Water Supply: Percent of Spaces in Use Class with Water Supply	Facilities with Wells	Percent of Facilities in Use Class with Wells
Residential	10	163	7.2	21,228	8.7	162	99.4	21,211	99.9	34	20.9
Educational	20	240	10.6	37,855	15.4	225	93.8	37,025	97.8	63	26.3
Religious	30	181	8.0	16,719	6.8	169	93.4	16,322	97.6	45	24.9
Government and Public Service	40	240	10.6	29,879	12.2	228	95.0	29,152	97.6	34	14.2
Commercial	50	1,068	47.1	96,308	39.3	1,033	96.7	94,726	98.4	144	13.5
Industrial	60	76	3.4	14,404	5.9	72	94.7	14,047	97.5	27	35.5
Amusement/ Meeting	70	73	3.2	9,406	3.8	70	95.9	9,265	98.5	21	28.8
Transportation	80	221	9.7	18,813	7.7	199	90.0	17,055	90.7	28	12.7
Miscellaneous	99	6	0.3	539	0.2	6	100.0	539	100.0	0	0.0
TOTAL		2,268	100.1 [5/]	245,151	100.0	2,164	95.4	239,342	97.6	396	17.5

(Continued)

Table 5. Four-County 1/ Summary of Small Congregate Care Facility Characteristics 2/ (Continued)

	Water Supply (cont'd)		Commodes					Generators	
Building Use	Spaces Served by Wells	Percent of Spaces in Use Class Served by Wells	Existing Commodes	Facilities with Sufficient Number of Commodes 3/	Percent of Use Class with Sufficient Number of Commodes	Additional Commodes Needed 4/	Deficit of Commodes per 1,000 People	Number of Facilities with Generator	Percent of Facilities in Use Class with Generator
Residential	1,840	8.7	1,682	157	96.3	10	0.5	0	0.0
Educational	8,883	23.5	1,045	137	57.1	221	5.8	0	0.0
Religious	2,792	16.7	434	119	65.7	86	5.1	0	0.0
Government and Public Services	3,914	13.1	814	159	66.3	165	5.5	20	8.3
Commercial	9,936	10.3	2,285	708	66.3	789	8.2	2	0.2
Industrial	3,817	26.5	144	20	26.3	189	13.1	0	0.0
Amusement/ Meeting	2,445	26.0	222	52	71.2	44	4.7	1	1.4
Transportation	2,073	11.0	336	121	54.8	238	12.7	0	0.0
Miscellaneous	0	0.0	21	4	66.7	2	3.7	0	0.0
TOTAL	35,700	14.6	6,983	1,477	65.1	1,744	7.1	23	1.0

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Small facilities are those facilities listed on the CRP (Crisis Relocation Planning) Host Areas Facility Listing from 4 arbitrarily selected U.S. counties that have less than 1,000 shelter spaces.
3/ Based on a minimum requirement of 1 commode per 50 shelter spaces.
4/ Commodes needed to bring facilities with fewer than the minimum requirement for commodes up to the minimum number required.
5/ Percentages do not total 100 percent due to rounding.

Table 6. Comparison of Four-County [1] Large and Small Shelter Facility Characteristics [2]

Building Use	Use Class	Facility Size	Number of Facilities	Percent of Total Facilities	Shelter Spaces	Percent of Total Spaces	Water Supply: Percent of Facilities in Use Class with Water	Water Supply: Percent of Spaces in Use Class with Water	Water Supply: Percent of Facilities in Use Class with Wells	Water Supply: Percent of Spaces in Use Class Served by Wells
Residential	10	Small	145	8.9	46,836	10.9	99.3	99.9	20.7	12.8
		Large	13	7.2	15,520	2.7	100.0	100.0	0.0	0.0
Educational	20	Small	177	10.9	64,778	15.1	92.1	95.4	21.5	23.5
		Large	53	29.4	138,353	24.5	100.0	100.0	26.4	36.8
Religious	30	Small	101	6.2	27,420	6.4	96.0	98.3	20.8	12.7
		Large	6	3.3	6,844	1.2	100.0	100.0	0.0	0.0
Government and Public Service	40	Small	179	11.0	53,217	12.4	96.6	97.2	14.5	10.6
		Large	58	32.2	173,114	30.6	100.0	100.0	0.0	0.0
Commercial	50	Small	817	50.2	187,679	43.9	97.7	98.4	13.1	11.2
		Large	32	17.8	104,774	18.5	100.0	100.0	3.1	1.2
Industrial	60	Small	26	1.6	8,546	2.0	96.2	99.5	61.5	56.4
		Large	14	7.8	122,181	21.6	92.9	98.4	7.1	1.6
Amusement/ Meeting	70	Small	43	2.6	12,280	2.9	97.7	99.6	41.9	21.9
		Large	2	1.1	2,100	0.4	100.0	100.0	50.0	52.4
Transportation	80	Small	136	8.4	26,449	6.2	89.0	82.7	11.0	11.7
		Large	2	1.1	2,679	0.5	50.0	42.9	0.0	0.0
Miscellaneous	99	Small	3	0.2	622	0.1	100.0	100.0	0.0	0.0
		Large	0	0.0	0	0.0	--	--	--	--
TOTAL		Small	1,627	100.0	427,827	99.9 [4]	96.3	97.0	16.7	14.5
		Large	180	99.9 [4]	565,565	100.0	98.9	99.4	9.4	9.8

(Continued)

Table 6. Comparison of Four-County 1/ Large and Small Shelter Facility Characteristics 2/ (Continued)

Building Use		Commodes: Facilities with Sufficient Number of Commodes 3/	Commodes: Percent of Facilities in Use Class with Sufficient Number of Commodes	Commodes: Deficit of Commodes per 1,000 People	Generators: Percent of Facilities in Use Class with Generator
Residential	Small	117	80.7	1.6	0.0
	Large	6	46.2	3.2	0.0
Educational	Small	30	16.9	11.8	0.0
	Large	1	1.9	13.5	0.0
Religious	Small	16	15.8	12.0	0.0
	Large	0	0.0	13.0	0.0
Government and Public Service	Small	32	17.9	11.0	8.4
	Large	24	41.4	9.0	25.9
Commercial	Small	153	18.7	13.1	0.2
	Large	0	0.0	18.4	0.0
Industrial	Small	3	11.5	12.8	0.0
	Large	1	7.1	17.8	21.4
Amusement/ Meeting	Small	8	18.6	11.3	0.0
	Large	1	50.0	8.6	0.0
Transportation	Small	42	30.9	14.4	0.0
	Large	0	0.0	19.0	0.0
Miscellaneous	Small	2	66.7	4.8	0.0
	Large	0	--	--	--
TOTAL	Small	403	24.8	11.3	1.0
	Large	33	18.3	13.6	10.0

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Large facilities are those buildings listed on the CRP Host Areas Facility Listing from 4 arbitrarily selected U.S. counties that have 1,000 or more shelter spaces; small facilities are those buildings that have less than 1,000 shelter spaces.
3/ Based on a minimum requirement of 1 commode per 50 shelter spaces.
4/ Percentages do not total 100 percent due to rounding.

building distribution by use class varies a great deal between large and small shelter facilities. For instance, an examination of the "Percent of Total Spaces" column indicates that the percentages vary by factors of from 1.6 in the educational use class to over 12 in the transportation use class (excluding the miscellaneous use class that only contains three small buildings). Therefore, it appears that there should be a significant difference in the types of large and small shelter facilities that are found in a host area. The provision of ventilation is particularly affected by the building use class. When comparing the large and small shelter facility water supply data, it appears that most buildings have existing water supply systems, regardless of size. However, it seems that small facilities are more likely to be served by wells than are large facilities. There is also a notable variation within use classes in the percentage of shelter facilities and shelter spaces served by wells. Table 6 indicates that small shelter facilities are approximately 36 percent more likely to have a sufficient number of commodes. By use class, small shelter facilities hold a greater chance of containing a sufficient number of commodes in all but two classes: government and public services and amusement/meeting. Finally, Table 6 indicates that 10 percent of large shelter facilities contain generators versus 1 percent of small shelter facilities.

Table 7 presents a comparison of four-county large and small congregate care facility characteristics. Examination of Table 7 shows the comparisons following basically the same pattern as the comparisons of large and small shelter facility characteristics. Therefore, factors that were emphasized in the shelter facility comparisons also apply to large and small congregate care facility comparisons.

Table 7. Comparison of Four-County [1] Large and Small Congregate Care Facility Characteristics [2]

Building Use	Use Class	Facility Size	Number of Facilities	Percent of Total Facilities	Congregate Care Spaces	Percent of Total Spaces	Water Supply: Percent of Facilities in Use Class with Water	Water Supply: Percent of Spaces in Use Class with Water	Water Supply: Percent of Facilities in Use Class with Wells	Water Supply: Percent of Spaces in Use Class Served by Wells
Residential	10	Small	163	7.2	21,228	8.7	99.4	99.9	20.9	8.7
		Large	13	6.7	8,018	3.2	100.0	100.0	0.0	0.0
Educational	20	Small	240	10.6	37,855	15.4	93.8	97.8	26.3	23.5
		Large	54	27.8	44,084	17.5	100.0	100.0	25.9	33.3
Religious	30	Small	181	8.0	16,719	6.8	93.4	97.6	24.9	16.7
		Large	6	3.1	2,635	1.0	100.0	100.0	0.0	0.0
Government and Public Services	40	Small	240	10.6	29,879	12.2	95.0	97.6	14.2	13.1
		Large	59	30.4	94,206	37.3	100.0	100.0	0.0	0.0
Commercial	50	Small	1,068	47.1	96,308	39.3	96.7	98.4	13.5	10.3
		Large	38	19.6	47,967	19.0	100.0	100.0	2.6	0.6
Industrial	60	Small	76	3.4	14,404	5.9	94.7	97.5	35.5	26.5
		Large	18	9.3	52,129	20.6	94.4	98.1	5.6	1.0
Amusement/ Meeting	70	Small	73	3.2	9,406	3.8	95.9	98.5	28.8	26.0
		Large	2	1.0	837	0.3	50.0	54.4	50.0	32.9
Transportation	80	Small	221	9.7	18,813	7.7	90.0	90.7	12.7	11.0
		Large	4	2.1	2,675	1.1	100.0	100.0	0.0	0.0
Miscellaneous	99	Small	6	0.3	539	0.2	100.0	100.0	0.0	0.0
		Large	0	0.0	0	0.0	--	--	--	--
TOTAL		Small	2,268	100.1 [4]	245,151	100.0	95.4	97.6	17.5	14.6
		Large	194	100.0	252,551	100.0	99.0	99.5	8.8	6.2

(Continued)

Table 7. Comparison of Four-County 1/ Large and Small Congregate Care Facility Characteristics 2/ (Continued)

		Commodes			Generators
Building Use		Facilities with Sufficient Number of Commodes 3/	Percent of Facilities in Use Class with Sufficient Number of Commodes	Deficit of Commodes per 1,000 People	Percent of Facilities in Use Class with Generator
Residential	Small	157	96.3	0.5	0.0
	Large	13	100.0	0.0	0.0
Educational	Small	137	57.1	5.8	0.0
	Large	33	61.1	4.6	0.0
Religious	Small	119	65.7	5.1	0.0
	Large	3	50.0	4.2	0.0
Government and Public Services	Small	159	66.3	5.5	8.3
	Large	35	59.3	2.0	25.4
Commercial	Small	708	66.3	8.2	0.2
	Large	5	13.2	12.7	0.0
Industrial	Small	20	26.3	13.1	0.0
	Large	5	27.8	12.7	16.7
Amusement/ Meeting	Small	52	71.2	4.7	1.4
	Large	1	50.0	2.4	0.0
Transportation	Small	121	54.8	12.7	0.0
	Large	0	0.0	16.1	0.0
Miscellaneous	Small	4	66.7	3.7	0.0
	Large	0	--	--	--
TOTAL	Small	1,477	65.1	7.1	1.0
	Large	95	49.0	6.6	9.3

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Large facilities are those buildings listed on the CRP Host Areas Facility Listing from 4 arbitrarily selected U.S. counties that have 1,000 or more shelter spaces; small facilities are those buildings that have less than 1,000 shelter spaces.
3/ Based on a minimum requirement of 1 commode per 50 shelter spaces.
4/ Percentages do not total 100 percent due to rounding.

IV. DESCRIPTION OF OPTIONS FOR PROVIDING SERVICES

The development of descriptions of methods for augmenting the existing services or for implementing new systems for providing services in small host area shelters is accomplished in three steps. First, guidelines are developed upon which to base estimates of the minimum required services during a shelter stay. Second, the existing services in small facilities are estimated from the facility characteristics as defined in the preceding section. The estimated services are then evaluated and compared to the required levels in order to measure the adequacy of existing services and to allow specification of the amount of upgrading required. Finally, methods of achieving the required upgrading are defined.

In the large shelter space study [Ref. 1], congregate care facilities were not considered in describing options for providing services. The following three reasons for this lack of consideration were listed: (1) on the basis of the four-county host area survey results, the vast majority of large congregate care facilities also serve as fallout shelters during a crisis period and, therefore, require services to support the greater population that is housed in a fallout shelter, (2) during the time that a facility is used for congregate care, the existing utility and waste disposal services should continue to operate, and (3) while a facility is being used for congregate care there should be no danger from fallout; so sufficient numbers of apertures can be left open to provide light and ventilation, and shelter occupants can find sources of water and means of waste disposal outside the facility. In the case of small facilities, the second and third statements listed above are still valid, but there are almost 40 percent more small congregate care facilities than shelter facilities in the four-county host area survey results presented in Tables 4 and 5. However, the smaller number of shelter facilities contain almost 75 percent more shelter spaces than the total number of congregate care spaces. Therefore, the upgrading requirements for a host area are still dependent on the requirements of the shelter facilities. When making plans for a specific host area, the adequacy of the water supply and waste disposal systems in the proximity of congregate care facilities should be noted. If it is determined that these systems offer insufficient capacity, plans

should be made for the provision of these services during the preattack period. No other special provisions seem to be necessary for the utilization of congregate care facilities. Hereafter, the emphasis of this study will be on fallout shelter facilities.

The following sections describe the options for providing lighting, ventilation, potable water supply, excreta disposal, and solid waste disposal systems in small fallout shelter facilities.

A. Lighting

In a facility that is to be used as a fallout shelter, the provision of at least a low level of illumination is essential. Light is needed in areas where tasks such as food preparation or solid waste collection must be performed; there should also be enough light throughout the shelter to allow people to navigate successfully. Furthermore, under the stress of a crisis situation, people will tend to become disoriented and frightened if inadequate lighting is provided.

1. Required Lighting

Very minimal levels of light are all that are required in a fallout shelter facility. Levels of light that prevent the shelter occupants from becoming lost and allow them to identify their immediate surroundings are sufficient. Tasks (such as food preparation) for which more light is essential should be performed near a light source.

2. Existing Lighting Systems

The building codes referenced in Section III are consistent in requiring windows of area not less than 10 percent of the floor area served or adequate means of providing artificial lighting in all use classes with the exception of residential buildings under the National Building Code [Ref. 2], which does not stipulate artificial light in the absence of windows. Based on this, the only conclusion that can be drawn is that interior rooms with no windows should be artificially lighted. In the large shelter space study [Ref. 1], it was assumed that all large buildings would be served by some amount of artificial lighting. Although this assumption is harder to defend when applied to small buildings, considering the availability of electricity in even remote areas of the United States, it is difficult to imagine a building with fallout shelter potential not having an artificial lighting system. Therefore, in this study it will again be assumed that all buildings within the scope of this report will contain some artificial lighting capabilities.

The four-county summary of small shelter facility characteristics presented in Table 4 shows that 8.4 percent of the buildings in the government and public services use class were found to be equipped with emergency generators. The commercial use class was the only other use class with any buildings containing generators (two buildings representing 2 percent of the buildings in the use class). Of the buildings classified as government and public services, most would be occupied by key workers during a crisis and would not be available for use as shelter for the general population. Therefore, with few exceptions, small buildings used as fallout shelters are not equipped with emergency generators; so sources of generators must be identified if existing lighting systems are to be utilized.

3. Provision of Lighting

Appendix A identifies some factors to be taken into consideration in utilizing a standby engine-generator in an existing building and presents guidelines for connecting engine-generators to the lighting systems in buildings. The portable engine-generators used by construction contractors (ranging in size from 750 to 5,000 watts) should be sufficient to power the lighting as well as the ventilation system required in a small building. This type of generator is the most prevalent emergency power source [Ref. 7] and should be available in virtually all areas of the country. If emergency generators are not available in the proper size or voltage, or if the building contains no artificial lighting system, then it is necessary to resort to other expedient means of providing lighting, such as candles, kerosene lamps, cooking fat lamps, etc. [Ref. 8].

B. Ventilation

Ventilation of a fallout shelter building is needed both to maintain the air quality within satisfactory limits, and to maintain the effective temperature at an acceptable level. Increases in carbon dioxide lead to symptoms ranging from much deeper breathing and considerable discomfort (4 percent carbon dioxide in inhaled air), to inability to coordinate with loss of consciousness after 10 minutes exposure (10 to 11 percent carbon dioxide in inhaled air), and finally, to gradual death after some hours (25 to 30 percent carbon dioxide in inhaled air) [Ref. 9]. Similarly, oxygen deficiencies lead to symptoms ranging from dizziness, shortness of breath, deeper and more rapid breathing, and quicker pulse, especially with

exertion (10 percent oxygen content of inhaled air); to stupor (7 percent oxygen content of inhaled air); to death within 1 minute (2 to 3 percent oxygen content of inhaled air) [Ref. 9]. Increase in effective temperature, while not accompanied by the severe symptoms associated with changes in air quality, does lead to symptoms ranging from possible heat rash with prolonged exposure, though endurable in emergencies for at least 2 weeks (85^0F effective temperature), to possible heat exhaustion among unacclimatized people (88^0F effective temperature), to possible heat exhaustion among acclimatized people (92^0F effective temperature)[Ref. 9].

1. Required Ventilation

A ventilation rate of 3 cfm per person is sufficient to keep oxygen and carbon dioxide levels adequate for survival. In a building occupied at 10 square feet per person, the volume of ventilation that is required to keep the effective temperature within tolerable limits (82^0F effective temperature) ranges from 5 to 50 cfm per occupant, depending on the geographic location [Ref. 10]. Therefore, it is important that the local planner be aware of the ventilation requirement in his particular host area. Regardless of the ventilation rate, proper distribution of the ventilating air is required in order to achieve the stated goals. It is important, therefore, that an effort be made to achieve a uniform distribution of the air over the shelter area.

2. Existing Ventilation Systems

As can be seen in Table 3, the four building codes referenced are consistent in requiring either windows with an aggregate openable area not less than one twentieth the floor area served as a source of natural ventilation, or a means of providing equivalent mechanical ventilation. The National Building Code [Ref. 1], through a reference to the ASHRAE Applications Handbook [Ref. 5], gives the most detailed and widely applicable guidelines of the four building codes for mechanical ventilation rates in the various use classes. In comparing the ventilation rates (recommended by the National Building Code as displayed in Table 3) to the required fallout shelter ventilation rate of 5 to 50 cfm per space (10 square feet), it is apparent that buildings in some use classes have the potential of offering adequate existing ventilation. The religious or amusement/meeting use classes call for mechanical ventilation rates of from 5 to 15 cfm of outside air per 10 square feet. The industrial use class

calls for from 15 to 30 cfm of outside air per 10 square feet. Based on these requirements in industrial buildings (which comprise 1.6 percent of the four-county host area sample) which contain mechanical ventilation systems, the ventilation capacity should be sufficient to support the fallout shelter populations in most parts of the country. Religious and amusement/meeting buildings (which comprise 8.8 percent of the four-county host area sample) with mechanical ventilation systems are expected to have adequate ventilation in some parts of the country, with the likelihood being higher in buildings in which smoking is allowed. From Table 3, it appears unlikely that buildings in the other use classes contain adequate mechanical ventilation systems.

In RTI's large shelter space study [Ref. 1], it was noted that most mechanical ventilation systems are equipped with dampers that limit the volume of outside air entering the facility such that the air circulated through a building is approximately 25 percent outside air and 75 percent recirculated air. In these cases, if the damper is opened to permit 100 percent outside air, the volume of outside air provided increases by a factor of four. It was found that when the rates recommended by the National Building Code are multiplied by four in buildings with mechanical ventilation systems, the ventilation volume should be adequate for the shelter population in most use classes in most parts of the country (except for stores under use class 50 and the additional possible exceptions of use class 10, and offices under use classes 40 and 50). However, many small buildings have closed mechanical ventilation systems, in which fresh air enters only through infiltration. Also, existing data do not give guidelines upon which to base estimates of the percentages of buildings which contain mechanical ventilation systems. Host areas in the warmer geographical regions of the country should contain more buildings with existing mechanical ventilation systems. It is also likely that relatively more large buildings than small buildings contain mechanical ventilation systems. However, more data is needed before these relationships can be quantified. Considering all of the above factors, it is unlikely that many small buildings will have mechanical ventilation systems that are adequate for shelter use.

3. <u>Provision of Ventilation</u>

As was the case with lighting, if existing mechanical ventilation systems are to be utilized during a shelter stay, they must be connected to

emergency power sources. It is pointed out in the lighting section that, on the basis of the four-county host area sample, it is not likely that small buildings used as fallout shelters are equipped with emergency generators. However, unlike the situation in some large buildings used as shelters, the lighting and ventilation load combined in a small building should be small enough to be powered by a portable engine generator used by construction contractors (ranging in size from 750 to 5,000 watts). As has been noted in the lighting section, this type of generator is the most prevalent emergency power source and should be available in virtually all areas of the country. Appendix A identifies factors which should be taken into consideration when utilizing an engine-generator in an existing building and presents guidelines for connecting an engine-generator into the electrical distribution system of a building.

In a building in which the existing mechanical ventilation system is inadequate or in which no mechanical system has been installed, provisions should be made for furnishing forced ventilation during a shelter period. It does not appear to be practical to try to augment an existing mechanical ventilation system of insufficient capacity. The analysis needed to design an expedient system to supply all of the ventilation required in a small building should be much less complex than the detailed analysis needed to identify a feasible means of augmenting the existing system.

RTI's large shelter space study [Ref. 1] recommends the use of industrial-type fans to ventilate a large shelter facility. However, in most small facilities the volume of air delivered by an industrial-type fan is not needed. As defined in this study, a small facility has less than 1,000 spaces, therefore, the maximum ventilation volume required in a small facility is 49,950 cfm in a shelter with 999 spaces located in a geographic zone requiring 50 cfm per occupant. Window and floor pedestal fans are available that deliver various volumes of air, ranging from less than 1,000 cfm to over 8,000 cfm, depending on blade diameter and motor horsepower. Depending on the sizes of fans available and the aperture areas and configurations in particular small facilities, window or floor pedestal fans should be suitable to ventilate most small shelter buildings. The advantages of using such fans include off-the-shelf availability (though availability is seasonal) and 115-volt motors that can simply be plugged into a regular wall receptacle that is fed by a circuit connected to the

emergency engine-generator. No 220-volt circuit or connection directly to the engine-generator is required.

According to the four building codes referenced in Section III, buildings in all use classes are expected to have enough openable window area to serve as air supply and exhaust openings for forced ventilation systems. During development of host area plans, air inlet and exhaust openings should be identified and should be located so that air will be distributed through as much of the building as possible. It will be most helpful if an engineer or technician experienced in the design and installation of mechanical ventilation systems is consulted at this stage of the planning effort. Also during the planning stage, sources of fans and engine-generators should be identified and arrangements made for the use and transportation of the equipment in the event of an emergency. Kearny pumps [Ref.8] may be used to distribute air within buildings to rooms or areas within rooms that otherwise do not receive ventilation. Identification of sources of materials with which to construct these devices should also be accomplished during the planning stages.

C. Water Supply

One of the essential elements in surviving an extended shelter stay is the provision of clean, safe water. While people can survive for extended periods (two or more weeks) without food, just a few days (two or three) without water can produce either serious physiological consequences or death. Water is especially critical to life support in a hot environment.

The need for an adequate water supply in a shelter during a nuclear crisis is obvious and must be met to ensure the welfare of the sheltered population. This need, as related to shelter facilities, is discussed herein, and includes descriptions of per capita water requirements, existing water service in shelter facilities, means of augmenting water supplies in shelters, and guidance on water disinfection.

1. Water Supply Requirements

According to the DCPA Attack Environment Manual [Ref. 10], one quart of water a day suffices to maintain the water balance, if people are not required to perspire to lose body heat. Perspiration is needed to lose body heat at air temperatures of greater than 70^{o}F. Therefore, it follows that the water requirement is partially a function of the ventilation rate in the shelter, as well as the outside temperature and humidity. The range of ventilation requirements stipulated in the last section was designed to

maintain the effective temperature at a maximum of $82^{0}F$ with a 90 percent reliability. At low humidities the air temperature can be quite high and still yield an effective temperature of $82^{0}F$ (e.g., $100^{0}F$ dry bulb and 20 percent humidity result in an effective temperature of $82^{0}F$). Figure 1 shows that the average daily water need increases exponentially with increases in air temperature. Hence, it is recommended that from 0.3 to 5.3 gallons (1 to 20 ℓ) of potable water per day (ideally, as close as possible to 5.3 gallons) be provided for each shelter occupant during the in-shelter period. A supply of from 4-5.3 gallons/capita-day should be sufficient for drinking, personal food preparation, and basic cleanliness [Ref. 11]--even in the hottest environments. Factors other than temperature and humidity that influence personal water requirements include: age, health, sex, and physical condition (e.g., pregnancy).

In addition to an adequate water supply, provisions must be made for water distribution in shelters. As a general guideline, one watering point (e.g., faucet in piped water supply, or tap in water tank) should be provided for each 100 persons [Ref. 12]. The watering points should be distributed throughout the shelter, not concentrated in a single location. The shelter configuration could result in a modification of the one watering point per 100 person guideline. For example, in a building that is partitioned into several small rooms, the provision of one faucet per room will enable each shelter occupant to easily obtain an adequate supply of water.

2. <u>Existing Water Service in Shelter Facilities</u>

Nearly all of the small shelter facilities in RTI's four-county host area survey have existing water supplies (96.3 percent of the small shelter buildings containing 97.0 percent of the small shelter facility spaces). The percentages of buildings and spaces are slightly smaller than the corresponding percentages for large facilities, but the differences do not appear to be significant. However, 16.7 percent of small facilities (containing 14.5 percent of the small shelter facility spaces) are supplied by wells as opposed to 9.4 percent of large facilities (containing 9.8 percent of the large shelter facility spaces). An examination of the use class data in Table 6 indicates that, in the four use classes in which no large shelter facilities were found to have wells (residential, religious, government and public services, and transportation), 20.7 percent, 20.8 percent, 14.5 percent, and 11.0 percent respectively of small shelter

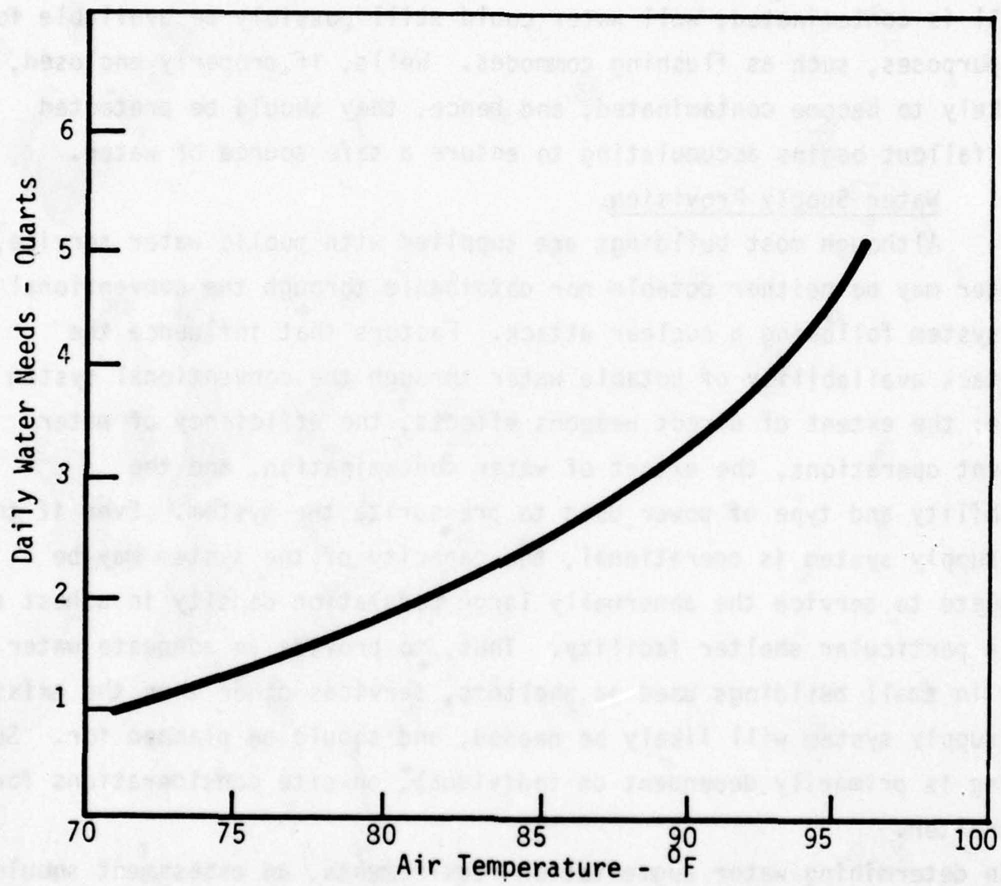


Figure 1. Minimum Water Required for Negligible Dehydration

facilities were found to have wells. Therefore, it appears that a small shelter facility is much more likely to be supplied with water from a well, particularly in the four use classes listed above.

The significance of wells is that they may provide a sizeable volume of potable water, if they are not contaminated with radioactive fallout, and that they are less likely to be disrupted after attack than a community water service. Of course, sufficient generating capacity must be provided to drive the pump in addition to the lighting and ventilation systems. If the well is contaminated, well water could still possibly be available for other purposes, such as flushing commodes. Wells, if properly enclosed, are not likely to become contaminated, and hence, they should be protected before fallout begins accumulating to ensure a safe source of water.

3. Water Supply Provision

Although most buildings are supplied with public water service, the water may be neither potable nor obtainable through the conventional water system following a nuclear attack. Factors that influence the postattack availability of potable water through the conventional system include: the extent of direct weapons effects, the efficiency of water treatment operations, the extent of water contamination, and the availability and type of power used to pressurize the system. Even if the water supply system is operational, the capacity of the system may be inadequate to service the abnormally large population density in a host area or in a particular shelter facility. Thus, to provide an adequate water supply in small buildings used as shelters, services other than the existing water supply system will likely be needed, and should be planned for. Such planning is primarily dependent on individual, on-site considerations for each shelter.

In determining water augmentation requirements, an assessment should be performed of the probable on-site, postattack water supply. For instance, as in the case of large facilities, the following questions should be addressed:

- Is the shelter supplied with a protected well?
- What is the capacity of the well?
- Are pumps, pipes, generators, etc., available to obtain water from the well?

- Is the equipment available to distribute water inside the shelter from a well, tank, or other water source?
- If the shelter is serviced by a public water supply, will this source be available in the postattack environment?
- Is the public water supply from a well, surface water reservoir, or other source?
- Is this source likely to be contaminated from fallout or other factors?
- Will the water treatment plant be operable postattack?
- Is the water supply system located in a high-risk area likely to have direct weapons effects upon water tanks, water pipes, and power?

Again, it should be stressed that this is just an example of some of the factors to consider in planning for adequate shelter water supply. Each host area in the country has a unique set of conditions that must be taken into account by the local planner.

Water can be obtained in shelters in several manners that have been pointed out in previous RTI studies. Several sources of water may be available within the building itself, such as the following:

- fire control tanks
- sprinkler systems
- hot water heaters
- supply pipes
- holding and gravity tanks
- water closet flush tanks
- air conditioning or chilled water systems
- heating tanks and systems
- indoor swimming pools
- hydraulic elevators using water
- reflector pools within building [Ref. 13]

However, the water quality should be carefully evaluated to make sure the water is safe for human consumption. This can be accomplished by means recommended by local or state public health departments; therefore, personnel from these departments should be consulted during the shelter implementation planning process.

Other water provision possibilities include stocking water in the shelter by using steel drums that have been disinfected (or that have plastic liners). Garbage cans and industrial drums can be used for this purpose, as well as the standard 17-1/2 gallon water drums supplied by DCPA. Tank trucks, such as milk or gasoline trucks, can be cleaned, disinfected, filled with potable water before the attack, and driven to the shelter site.

Railroad tank cars can be used in a similar manner where railroad tracks run into, or near buildings such as industrial facilities (small facilities are not as likely as large facilities to have access to railroad tracks).

The choice of method(s) for providing water is based largely on the quantity of potable water available from each of the sources discussed above. Probably the most preferable method for providing water is from sources within the building, but these sources are not likely to contain adequate amounts of water in most shelter facilities. Therefore, it is apparent that sources of water containers (drums, cans, tank trucks, etc.) should be identified prior to a crisis situation and that the storage capacity of these containers should be evaluated. Water drums supplied by DCPA are generally preferable to tanks and drums obtained from private individuals or companies, who will probably expect renumeration. However, if mobile tanks are to be used, sources of pumps, taps, and pipelines also should be located. These supplies are needed to distribute water within the shelter and to supply water from tanks parked outside the shelter. Great care must be exercised to ensure that all petroleum residues, or other materials, are completely removed from the tanks to prevent the water from being fouled and to prevent ingestion of toxic substances by the sheltered population. The risk of water contamination from available tanks should be considered when evaluating water provision alternatives. Another factor to consider is the number of shelter spaces available in the host area. If there is a shortage of spaces, it is certainly preferable to use tank trucks or railroad tank cars parked outside of the shelter facilities. While smaller tanks and drums can be stored outside, the large number required to provide adequate quantities of water for even a small shelter would require a much more elaborate system of pumps and pipelines.

Water containers can be filled from the individual facility's water service prior to the attack; however, the existing water system must be evaluated to determine if this procedure is feasible. For example, water usage in the host area may be greater than normal prior to the attack due to the filling of water containers by persons in their own homes, but this water demand could be offset by a curtailment of industrial operations that use great volumes of water in their normal manufacturing processes. The season also has a great influence on the amount of water available in many areas. Thus, preattack water usage in the host area and facility will need to be evaluated individually by civil preparedness planners.

4. Water Disinfection Guidelines

Truck and railroad tank cars, wells, and other shelter water storage containers and sources will need to be disinfected to prevent contamination of the water supply. Boiling water before drinking is one means of disinfecting water, but this method may be neither feasible, nor advisable, due to fire hazards and ventilation restrictions in the shelter. Chlorine compounds, e.g., chlorine bleach, and other disinfectants are readily available in most areas and can effectively disinfect water containers and purify water for drinking. Tables 11 and 12 of the large shelter space study [Ref. 1] show the amounts of chemicals needed to sterilize water containers and disinfect water for drinking purposes. In certain host areas, there may be a severe shortage of chemicals for water disinfection and other sanitation.

D. Sewage Disposal

Another important aspect of utilizing a small building as a shelter is the sanitary disposal of human excreta and other liquid waste from food preparation or personal hygiene. Excreta disposal practice must prevent fecal contamination of the soil, ground, and surface water and prevent flies and other pests from coming in contact with excreta. Otherwise, outbreaks of common vehicle- and vector-borne communicable diseases are likely to occur within the sheltered population.

1. Sewage Disposal Requirements

In the context of this report, sewage is made up of two components: human excreta, and waste water from cooking and/or cleaning. Each of thse components must be considered separately in determining the sewage disposal requirements in a small shelter.

Excreta loss occurs by four mechanisms: urine, feces, sweat, and insensible loss (skin evaporation, breath). Urine and feces constitute only about one-half of the total excreta loss [Ref. 14], but they are the only elements of human excreta that pose a sewage disposal problem. Sweat and insensible loss are removed from the shelter via the air supplied by the ventilation system. As a guide for determining sewage disposal capacity, per capita sewage production is assumed to be 42 oz/day (1,200 ml/day) urine and 3 oz/day (90 ml/day) feces, based on figures for the standard adult man and adult woman [Ref. 14]. Thus, the daily per capita excreta production is determined to be 45 oz (1,290 ml). Excreta loss through urine and feces can be influenced by water intake and diet (in particular, urine production is reduced by about one-half when water intake is restricted or negligible

[Ref. 10], but 45 oz/capita-day should be considered an upper limit on the amount of excreta produced during a shelter stay.

As was indicated under "Water Supply Provision," more water must be provided per person in host areas with high air temperatures and low humidities. Certain quantities of water (up to the amounts shown in Figure 1) at various air temperatures will not cause increases in the amount of sewage produced. More excreta will be lost through perspiration and insensible loss, but this does not have to be handled by the sewage disposal system in the shelter. However, quantities of water in excess of the amounts shown in Figure 1 (based on the upper end of the water provision recommendation, a maximum excess of about 5 gal/capita-day) are to be used in cooking and cleaning. This water becomes waste water, which must be disposed of through the sewage disposal system. Therefore, the daily per capita sewage disposal requirement will be 45 oz of excreta plus any water that is provided beyond that required for negligible dehydration.

DCPA recommends 1 toilet per 50 shelter occupants. This figure is adequate and should be used for planning purposes, though a more desirable number of toilets is 7 per 50 shelter occupants. If sufficient resources are available (including space within the shelter), as many as 7 toilets per 50 shelter occupants should be provided.

2. Existing Sewage Disposal Facilities

As was the case with large shelters, the basic problem of sewage disposal in a small shelter stems from the fact that most facilities have not been originally constructed to accommodate a large occupant density over an extended period of time. Table 4 indicates that 24.8 percent of the small buildings in the four-county survey contained a sufficient number of commodes. Table 4 also shows that, on the average, there is a deficit of 11.3 commodes per 1,000 shelter spaces in small facilities. However, there are wide variations among the use classes, ranging from a deficit of only 1.6 commodes per 1,000 shelter spaces in residential buildings to a deficit of 14.4 commodes per 1,000 shelter spaces in transportation facilities. Of course, the use of the existing sewage disposal facilities is dependent upon the availability of water during a crisis situation. Therefore, the usefulness of existing facilities, and thus, the upgrading required for proper sewage disposal in each shelter facility, must be considered individually by the local civil preparedness planner. It does appear that at least some augmentation of the existing sewage disposal facilities will be needed in most small shelters.

3. Methods of Shelter Sewage Disposal

Once the necessary degree of upgrading for sewage disposal has been determined, provisions must be made to supply the needed materials and equipment to develop the needed disposal capacity. The provisions, however, will vary greatly according to the type of facility being upgraded as well as to the conditions in the particular host area. Hence, in developing plans for the most effective means of meeting the demands for sewage disposal, each facility in a host area should first be considered individually, and then, collectively. Certain methods and considerations which can be applied generally to any facility and/or host area are discussed in this section.

The most desirable method of disposing of sewage in a shelter is through existing flush toilets and sewage disposal systems. Practically, alternative methods of sewage disposal should be planned for as contingencies because: (1) the existing toilets may not be usable following the attack; and (2) the existing toilets, if usable, will not provide adequate sewage disposal capacity in most shelters.

Existing toilets may not be usable after a nuclear attack if the water supply to the toilets is interrupted. Providing the water supply system remains intact and operable, flush toilets can be used as normal, even if the water is contaminated with fallout and is nonpotable. If an adequate supply of waste water is available, this can be used to flush excreta and other semi-solid wastes should no piped-in water be available.

In selecting a method, or methods, of augmenting the existing system or of providing a complete sewage disposal system, the following criteria should be observed:

> In general, any method of excreta disposal that is considered should confine excreta; prevent contamination of water supply; provide convenience and privacy; and be clean and relatively odor free. From a practical standpoint, the disposal method chosen should be simply and quickly constructed, easily maintained, operable with a minimum reliance on the individual user, reliable over an extended period of time, and utilize resources in a cost-effective manner [Ref. 1].

Inside a shelter facility, the most feasible auxiliary sewage disposal methods are those that are self-contained, such as chemical toilets and removable pail privies. Chemical toilets are more desirable, since they are

totally enclosed and provide a capacity of from 125 to 250 gallons per seat. However, availability of chemical toilets in a host area will probably limit their use. If removable pail privies are needed, they should be walled-off from the rest of the facility and from each other by curtains, sheets, plywood walls, etc., to provide privacy. Sources of materials for the screens as well as sources of pails should be identified in the planning period. Water containers can be used as toilets, or as collection containers, depending on their size. Further planning should include provisions for a collection service and cleaning facilities. Sources of supplies of detergents should be identified regardless of which type of excreta disposal method is chosen.

Table 14 in the large shelter space study [Ref. 1] describes the above methods of sanitary excreta disposal, as well as several methods requiring soil. The feasibility of using disposal methods that require soil inside a shelter facility is low, since soil is not easily accessible through the floors of most facilities. However, due to the likelihood that shelter occupants might be able to leave the shelter for brief periods of time soon after nuclear attack, sewage disposal facilities that are located outside the shelter may be feasible.

Particularly around shelter facilities whose fallout protection factors are upgraded by piling earth against exterior walls and on the roof, earth trenches can be used for waste disposal. With careful planning, the digging of these trenches can serve a dual purpose: the provision of a pit for sanitary waste disposal, and a source of earth for use in upgrading. Sewage can be disposed of through trenches in two different ways: (1) toilet seats can be built over the trenches forming a large sanitary earth pit privy, or (2) sewage collected from pail privies inside the shelter can be dumped into the trenches, either by hand from the pails or pumped from collection areas inside the shelter (sumps, chemical or food vats, etc.) into the trench. Great care must be exercised in using heavy construction equipment to dig large trenches so that underground electricity, gas, sewage and water lines are not disrupted. Also, careful planning is needed to prevent contamination of ground water that is to be used as a source of drinking water.

Another alternative for disposing of sewage outside the shelter is the use of sewer lines near the shelter which are accessible by manholes.

By removing the manhole cover, a voluminous area is exposed that is desirable for sewage and waste disposal. Sewage can be transported to the sewer lines in pails or pumped through pipelines from collection areas inside the shelter.

The limiting factors of extraneous shelter sewage disposal are the availability of open space (preferably unpaved) outside the facility and the existing radiation levels. The former will have to be considered on an individual shelter basis prior to implementation; the latter is also an individual shelter consideration to be determined after the attack by shelter managers using approved radiation-measuring equipment. Table 8 shows general estimates of the consequences of radiation expected from short-term external gamma radiation dose or an equivalent residual dose (ERD) that has not exceeded 200 r (roentgen). The table indicates that exposures to levels below 200 r generally do not require medical attention; exposures below 50 r are probably acceptable for shelter occupants going outside the shelter for brief periods. Thus, with careful control, radiation levels can be monitored to limit radiation exposures so that shelter occupants can go outside the shelter for sanitary reasons, water, and other missions.

E. Solid Waste Disposal

In order to maintain a sanitary environment in a shelter, provisions must be made for proper solid waste disposal. Indiscriminate disposal can lead to a variety of problems, including odors, flies, rats, roaches, crickets, wandering dogs and cats, and fires [Ref. 15]. The following discussion will deal with factors associated with solid waste production and disposal as related to fallout shelters located in large facilities. Topics to be covered are the composition, per capita production, and disposal methods.

1. Composition and Production

The solid waste disposal problem in small shelters is virtually identical to the problem in large shelters. A large portion of the solid waste generated is expected to be the result of food preparation and mass feeding operations; hence, the waste will include cans, jars, plastic wrapping, boxes, disposable tableware, plates, trays, and cookware.

Table 8. Estimated Consequences of Short Term External 1/
Gamma Radiation Doses

Consequences or effects	Short term dose ERD (Equivalent Residual Dose)
Smallest effect detectable by statistical study of blood counts of a large group of people	15 r
Smallest effect detectable in an individual by laboratory methods	50 r
Smallest dose that causes vomiting on day of exposure in at least 10 percent of the people.	75 r
Smallest dose that causes epilation (loss of hair) in at least 10 percent of the people	100 r
Largest dose that does not cause illness severe enough to require medical care in majority of people (more than 90 percent of the people).	200 r
Dose that would be fatal to about 50 percent of the people	450 r
Dose that would be fatal to almost everyone	600 r

1/ "RADEF Fundamentals," Part E, Chapter 5, Appendix 1, Federal Civil Defense Guide, Office of Civil Defense, Department of Defense, June 15, 1963.

Personal hygiene practices will also lead to solid waste generation. In addition, the high probability and necessity of corpse disposal should be considered.

The per capita solid waste production varies widely in the United States due to numerous factors such as season, urban or rural location, and personal factors (such as economic status, education, and social habits). However, in a shelter environment, per capita solid waste production should be dependent on the amounts and types of food supplied and on the water supply (large quantities of water would accomodate more mass feeding and cleaning). Therefore, the quantity of solid waste anticipated should be evaluated on the basis of factors within each individual shelter facility. In the absence of specific DCPA guidelines concerning the production rate of solid waste in shelters, RTI proposes a per capita solid waste production rate in the range of 1.5 to 2.5 lbs/day (.68 to 1.1 kg/day) to be used for planning purposes [Ref. 1].

2. <u>Disposal Methods</u>

Since the differences in facility characteristics between small and large facilities generally are not significant to solid waste disposal, the options available for disposing of solid wastes in small facilities are essentially identical to those in large facilities. In general terms, there are two options: solid waste disposal on site or off site, with alternative methods available within each option. The following paragraphs describe how to implement each option in such a manner as to insure that health hazards will not be created by solid waste, regardless of the method selected.

The method of solid waste collection within the shelter that is most suitable for short-term stays is the provision of collection cans and bins. Independent of the method of solid waste disposal that is chosen, cans and bins will be necessary for temporary holding of solid waste. Waste containers of 26-gal (100 ℓ) capacity, or less, should be provided at the rate of 3 or 4 containers per 100 people. These containers should be washable, watertight, and have tight-fitting, overlapping lids [Ref. 11]. Plastic liners in the containers would aid in disposal routines and also provide more sanitary conditions by keeping the containers cleaner than those not having liners. Regular galvanized garbage cans for home use are well-suited for this method and should be located conveniently to as many

people as is feasible. In large shelters, it is recommended that the cans be located in groups of about 20 to 30 to expedite emptying and maintenance routines. In small shelters the groups should generally be kept to about 3 to 4 cans so that the cans can be conveniently located. When a collection container is full, the solid waste can be either transferred to a large storage container or disposed of directly.

Facilities should be available for the cleaning of the small collection containers at or near the site where they are emptied. To facilitate the cleaning process, the cleaning of solid waste collection and sewage disposal containers should be done at the same site. Disinfectants must be provided, both for the containers and to apply to the waste before its disposal. In addition, exposed waste should be sprayed systematically with insecticides, and rodent control measures instituted.

Large storage containers can be used to store the solid waste until nuclear radiation dies to sufficiently low levels to permit disposal on site or transportation to a disposal location off site. For example, containerized trash bins can be provided. In some small facilities, it may be feasible to locate the dumpster inside the shelter, though it will probably be necessary to locate it just outside an entrance (preferably not one of the air-intakes) where the small containers can be emptied into the dumpster. Large mobile containers can also be used for temporary storage. Compactor-type garbage trucks are ideal for this purpose.

Burial in trenches, if practical, is a highly recommended method of on-site solid waste disposal for small shelter facilities. This method involves digging trenches in open areas adjacent to the shelters. The same considerations related to radiation levels and the location of the trenches that were mentioned previously for sewage disposal also apply in the case of solid waste disposal. In fact, the same trench could be used for both sewage and solid waste disposal. The solid waste is periodically dumped from the small collection containers, or from the large storage containers, into a trench when radiation levels are low enough. After dumping, the solid waste is covered by dirt, either by hand (shovels) or by available earthmoving equipment. This method is adapted after the design of sanitary landfills which are used by many communities for solid waste disposal. A big advantage of this method is that relatively little post-shelter

operation effort will need to be devoted for sanitary disposal of solid waste since the trench can be covered with dirt in a short amount of time.

Another method of disposing of solid waste at the shelter site is incineration. Figure 1 of the large shelter space study [Ref. 1] illustrates suitable expedient incinerating methods. Another type of incinerator is the basket incinerator, which is simply a wire basket standing on stone or metal supports [Ref. 1]. Incineration is not recommended during the period that the shelter is occupied, due to the possibility of noxious fumes and shelter fire. For these same reasons, use of existing incinerators in buildings is not recommended. Of course, any time that incineration is employed, precautionary measures should be taken to assure that accidental incineration does not occur.

Off-site disposal of solid waste involves essentially the same methods as on-site disposal. The large storage containers are transported to a location off site (e.g., sanitary landfill, incinerator) where the solid waste is disposed of. This can be done when the radiation decays to very low levels or after the shelter stay if sufficient storage capacity is available on site.

V. THE RELATIONSHIPS OF GROUP SIZE AND OCCUPANT DENSITY TO THE PROVISION OF SERVICES

It is unlikely that there is a one-to-one correspondence between potential shelter occupants and available shelter spaces in any host area in the country. Therefore, the local planner must determine the best method to effectively utilize the shelter resources in a particular host area. If there are more spaces available than are needed, two possible shelter alternatives include:

- the use of only part of the available shelter facilities, in which case choices must be made among various sizes and types of facilities, or
- the reduction of the occupant density to less than one person per 10 square feet in all or part of the available shelter facilities.

If there is a shortage of spaces available, one possible alternative is to increase the occupant density to greater than one person per 10 square feet in all or part of the available shelter facilities. It should be emphasized that these are not all of the alternatives available in either case; these are merely the alternatives affected by the discussion presented herein. In the pages that follow, some factors relating to the effects of group size and occupant density on the provision of services are examined. Within the context of this study, facility size is the major determinant of group size. The factors covered should be considered by the local planner as an aid in developing the shelter plan for a particular host area.

Table 9 presents a comparison of facility characteristics by facility size for all of the facilities in the four-county host area survey. Although basically the same format as Table 6, this table gives a more detailed breakdown by facility size, and more clearly delineates trends in facility characteristics. Once again, the entries preceding the water supply data contain facility and shelter space distributions by use class; the remaining entries are divided into sections which characterize existing water supply, sewage disposal, and emergency power services.

Some general observations concerning the utilization of small facilities versus large facilities can be made. With regard to the planning

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size

Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Total Facilities with Water Supply	Water Supply: Facilities with Wells	Water Supply: Percent of Total Facilities with Wells
1-99 Spaces	Residential	10	12	0.66	860	0.09	11	0.63	2	0.69
	Educational	20	17	0.94	1,096	0.11	14	0.80	0	0.00
	Religious	30	14	0.77	855	0.09	12	0.69	4	1.39
	Government and Public Services	40	34	1.88	2,240	0.23	32	1.84	7	2.43
	Commercial	50	180	9.96	12,454	1.25	172	9.87	32	11.11
	Industrial	60	8	0.44	438	0.04	7	0.40	5	1.74
	Amusement/ Meeting	70	8	0.44	549	0.06	7	0.40	3	1.04
	Transportation	80	53	2.93	3,902	0.39	48	2.75	4	1.39
	Miscellaneous	99	1	0.06	60	0.01	1	0.06	0	0.00
	SUBTOTAL		327	18.08	22,454	2.27	304	17.44	57	19.79

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

		Commodes					Generators	
Building Size	Building Use	Existing Commodes	Facilities with Sufficient Number of Commodes 2/	Percent of Total Facilities with Sufficient Number of Commodes	Additional Commodes Needed 3/	Deficit of Commodes per 1,000 People	Number of Facilities with Generator	Percent of Total Facilities with Generator
1-99 Spaces	Residential	39	11	2.53	2	2.3	0	0.00
	Educational	27	5	1.15	20	18.2	0	0.00
	Religious	20	9	2.07	8	9.4	0	0.00
	Government and Public Services	54	15	3.45	22	9.8	2	5.71
	Commercial	247	93	21.38	99	7.9	1	2.86
	Industrial	11	3	0.69	6	13.7	0	0.00
	Amusement/ Meeting	14	4	0.92	4	7.3	0	0.00
	Transportation	82	38	8.74	18	4.6	0	0.00
	Miscellaneous	2	1	0.23	0	0.0	0	0.00
	SUBTOTAL	496	179	41.16	179	8.0	3	8.57

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Total Facilities with Water Supply	Water Supply: Facilities with Wells	Water Supply: Percent of Total Facilities with Wells
100-499 Spaces	Residential	10	105	5.81	28,066	2.83	105	6.02	26	9.03
	Educational	20	114	6.31	30,619	3.08	103	5.91	27	9.38
	Religious	30	74	4.10	18,062	1.82	72	4.13	17	5.90
	Government and Public Services	40	117	6.47	31,983	3.22	114	6.54	17	5.90
	Commercial	50	561	31.05	123,206	12.40	550	31.55	69	23.96
	Industrial	60	12	0.66	3,642	0.37	11	0.63	8	2.78
	Amusement/ Meeting	70	26	1.44	6,071	0.61	26	1.49	13	4.51
	Transportation	80	71	3.93	13,429	1.35	65	3.73	10	3.47
	Miscellaneous	99	2	0.11	562	0.06	2	0.11	0	0.00
	SUBTOTAL		1,082	59.88	255,640	25.74	1,048	60.11	187	64.93

(Continued)

Table 9. Comparison of Four-County 1/ Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Commodes					Generators	
		Existing Commodes	Facilities with Sufficient Number of Commodes 2/	Percent of Total Facilities with Sufficient Number of Commodes	Additional Commodes Needed 3/	Deficit of Commodes per 1,000 People	Number of Facilities with Generator	Percent of Total Facilities with Generator
100-499 Spaces	Residential	889	86	19.77	28	1.0	0	0.00
	Educational	421	19	4.37	362	11.8	0	0.00
	Religious	187	7	1.61	213	11.8	0	0.00
	Government and Public Services	367	14	3.22	363	11.3	9	25.71
	Commercial	1,219	58	13.33	1,570	12.7	1	2.86
	Industrial	18	0	0.00	31	8.5	0	0.00
	Amusement/Meeting	66	4	0.92	64	10.5	0	0.00
	Transportation	118	4	0.92	190	14.1	0	0.00
	Miscellaneous	15	1	0.23	3	5.3	0	0.00
	SUBTOTAL	3,300	193	44.37	2,824	11.0	10	28.57

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Total Facilities with Water Supply	Water Supply: Facilities with Wells	Water Supply: Percent of Total Facilities with Wells
500-999 Spaces	Residential	10	28	1.55	17,910	1.80	28	1.61	2	0.69
	Educational	20	46	2.55	33,063	3.33	46	2.64	11	3.82
	Religious	30	13	0.72	8,503	0.86	13	0.75	0	0.00
	Government and Public Services	40	28	1.55	18,994	1.91	27	1.55	2	0.69
	Commercial	50	76	4.21	52,019	5.24	76	4.36	6	2.08
	Industrial	60	7	0.39	4,866	0.49	7	0.40	3	1.04
	Amusement/ Meeting	70	9	0.50	5,660	0.57	9	0.52	2	0.69
	Transportation	80	12	0.66	9,118	0.92	8	0.46	1	0.35
	Miscellaneous	99	0	0.00	0	0.00	0	0.00	0	0.00
	SUBTOTAL		219	12.13	150,133	15.12	214	12.29	27	9.36

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Commodes: Existing Commodes	Commodes: Facilities with Sufficient Number of Commodes 2/	Commodes: Percent of Total Facilities with Sufficient Number of Commodes	Commodes: Additional Commodes Needed 3/	Commodes: Deficit of Commodes per 1,000 People	Generators: Number of Facilities with Generator	Generators: Percent of Total Facilities with Generator
500-999 Spaces	Residential	615	20	4.60	45	2.5	0	0.00
	Educational	315	6	1.38	382	11.6	0	0.00
	Religious	68	0	0.00	107	12.6	0	0.00
	Government and Public Services	205	3	0.69	203	10.7	4	11.43
	Commercial	317	2	0.46	794	15.3	0	0.00
	Industrial	27	0	0.00	72	14.8	0	0.00
	Amusement/ Meeting	45	0	0.00	71	12.5	0	0.00
	Transporta- tion	14	0	0.00	173	19.0	0	0.00
	Miscella- neous	0	0	0.00	0	0.0	0	0.00
	SUBTOTAL	1,606	31	7.13	1,847	12.3	4	11.43

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Total Facilities with Water Supply	Water Supply: Facilities with Wells	Water Supply: Percent of Total Facilities with Wells
1,000-4,999 Spaces	Residential	10	13	0.72	15,520	1.56	13	0.75	0	0.00
	Educational	20	48	2.66	105,320	10.60	48	2.75	11	3.82
	Religious	30	6	0.33	6,844	0.69	6	0.34	0	0.00
	Government and Public Services	40	51	2.82	108,980	10.97	51	2.93	0	0.00
	Commercial	50	29	1.60	51,719	5.21	29	1.66	1	0.35
	Industrial	60	7	0.39	14,061	1.42	6	0.34	1	0.35
	Amusement/ Meeting	70	2	0.11	2,100	0.21	2	0.11	1	0.35
	Transportation	80	2	0.11	2,679	0.27	1	0.06	0	0.00
	Miscellaneous	99	0	0.00	0	0.00	0	0.00	0	0.00
	SUBTOTAL		158	8.74	307,223	30.93	156	8.94	14	4.87

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Commodes: Existing Commodes	Commodes: Facilities with Sufficient Number of Commodes 2/	Commodes: Percent of Total Facilities with Sufficient Number of Commodes	Commodes: Additional Commodes Needed 3/	Commodes: Deficit of Commodes per 1,000 People	Generators: Number of Facilities with Generator	Generators: Percent of Total Facilities with Generator
1,000-4,999 spaces	Residential	468	6	1.38	50	3.2	0	0.00
	Educational	793	1	0.23	1,388	13.2	0	0.00
	Religious	50	0	0.00	89	13.0	0	0.00
	Government and Public Services	2,113	24	5.52	621	5.7	13	37.14
	Commercial	134	0	0.00	903	17.5	0	0.00
	Industrial	47	0	0.00	235	16.7	0	0.00
	Amusement/ Meeting	24	1	0.23	18	8.6	0	0.00
	Transportation	3	0	0.00	51	19.0	0	0.00
	Miscellaneous	0	0	0.00	0	0.0	0	0.00
	SUBTOTAL	3,632	32	7.36	3,355	10.9	13	37.14

(Continued)

Table 9. Comparison of Four-County [1/] Shelter Facility Characteristics by Facility Size (Continued)

							Water Supply			
Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Facilities with Water Supply	Percent of Total Facilities with Water Supply	Facilities with Wells	Percent of Total Facilities with Wells
5,000-9,999 Spaces	Residential	10	0	0.00	0	0.00	0	0.00	0	0.00
	Educational	20	5	0.28	33,033	3.33	5	0.29	3	1.04
	Religious	30	0	0.00	0	0.00	0	0.00	0	0.00
	Government and Public Services	40	4	0.22	31,625	3.18	4	0.23	0	0.00
	Commercial	50	2	0.11	13,055	1.31	2	0.11	0	0.00
	Industrial	60	3	0.17	24,091	2.43	3	0.17	0	0.00
	Amusement/ Meeting	70	0	0.00	0	0.00	0	0.00	0	0.00
	Transportation	80	0	0.00	0	0.00	0	0.00	0	0.00
	Miscellaneous	99	0	0.00	0	0.00	0	0.00	0	0.00
	SUBTOTAL		14	0.78	101,804	10.25	14	0.80	3	1.04

(Continued)

Table 9. Comparison of Four-County [1]/Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Commodes: Existing Commodes	Commodes: Facilities with Sufficient Number of Commodes 2/	Commodes: Percent of Total Facilities with Sufficient Number of Commodes	Commodes: Additional Commodes Needed 3/	Commodes: Deficit of Commodes per 1,000 People	Generators: Number of Facilities with Generator	Generators: Percent of Total Facilities with Generator
5,000-9,999 spaces	Residential	0	0	0.00	0	0.0	0	0.00
	Educational	152	0	0.00	481	14.6	0	0.00
	Religious	0	0	0.00	0	0.0	0	0.00
	Government and Public Services	196	0	0.00	437	13.8	2	5.71
	Commercial	7	0	0.00	255	19.5	0	0.00
	Industrial	109	0	0.00	373	15.5	2	5.71
	Amusement/ Meeting	0	0	0.00	0	0.0	0	0.00
	Transportation	0	0	0.00	0	0.0	0	0.00
	Miscellaneous	0	0	0.00	0	0.0	0	0.00
	SUBTOTAL	464	0	0.00	1,546	15.2	4	11.42

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Total Facilities with Water Supply	Water Supply: Facilities with Wells	Water Supply: Percent of Total Facilities with Wells
10,000-19,999 Spaces	Residential	10	0	0.00	0	0.00	0	0.00	0	0.00
	Educational	20	0	0.00	0	0.00	0	0.00	0	0.00
	Religious	30	0	0.00	0	0.00	0	0.00	0	0.00
	Government and Public Services	40	3	0.17	32,509	3.27	3	0.17	0	0.00
	Commercial	50	0	0.00	0	0.00	0	0.00	0	0.00
	Industrial	60	1	0.06	12,750	1.28	1	0.06	0	0.00
	Amusement/ Meeting	70	0	0.00	0	0.00	0	0.00	0	0.00
	Transportation	80	0	0.00	0	0.00	0	0.00	0	0.00
	Miscellaneous	99	0	0.00	0	0.00	0	0.00	0	0.00
	SUBTOTAL		4	0.23	45,259	4.55	4	0.23	0	0.00

(Continued)

Table 9. Comparison of Four-County 1/ Shelter Facility Characteristics by Facility Size (Continued)

		Commodes					Generators	
Building Size	Building Use	Existing Commodes	Facilities with Sufficient Number of Commodes 2/	Percent of Total Facilities with Sufficient Number of Commodes	Additional Commodes Needed 3/	Deficit of Commodes per 1,000 People	Number of Facilities with Generator	Percent of Total Facilities with Generator
10,000-19,999 spaces	Residential	0	0	0.00	0	0.0	0	0.00
	Educational	0	0	0.00	0	0.0	0	0.00
	Religious	0	0	0.00	0	0.0	0	0.00
	Government and Public Services	150	0	0.00	500	15.4	0	0.00
	Commercial	0	0	0.00	0	0.0	0	0.00
	Industrial	30	0	0.00	225	17.6	1	2.86
	Amusement/ Meeting	0	0	0.00	0	0.0	0	0.00
	Transportation	0	0	0.00	0	0.0	0	0.00
	Miscellaneous	0	0	0.00	0	0.0	0	0.00
	SUBTOTAL	180	0	0.00	725	16.0	1	2.86

(Continued)

Table 9. Comparison of Four-County [1] Shelter Facility Characteristics by Facility Size (Continued)

Building Size	Building Use	Use Class	Number of Facilities	Percent of Total Facilities	Total Shelter Spaces	Percent of Total Shelter Spaces	Water Supply: Facilities with Water Supply	Water Supply: Percent of Total Facilities with Water Supply	Water Supply: Facilities with Wells	Water Supply: Percent of Total Facilities with Wells
20,000 Spaces or more	Residential	10	0	0.00	0	0.00	0	0.00	0	0.00
	Educational	20	0	0.00	0	0.00	0	0.00	0	0.00
	Religious	30	0	0.00	0	0.00	0	0.00	0	0.00
	Government and Public Services	40	0	0.00	0	0.00	0	0.00	0	0.00
	Commercial	50	1	0.06	40,000	4.03	1	0.06	0	0.00
	Industrial	60	2	0.11	70,879	7.14	2	0.11	0	0.00
	Amusement/ Meeting	70	0	0.00	0	0.00	0	0.00	0	0.00
	Transportation	80	0	0.00	0	0.00	0	0.00	0	0.00
	Miscellaneous	99	0	0.00	0	0.00	0	0.00	0	0.00
	SUBTOTAL		3	0.17	110,879	11.17	3	0.17	0	0.00
	TOTAL [4/]		1,807	100.01	993,392	100.03	1,743	99.98	288	99.99

1/ Baldwin County, Georgia; Clark County, Ohio; Yuba County, California; Yuma County, Arizona.
2/ Based on the minimum requirement of 1 commode per 50 shelter spaces.
3/ Commodes needed to bring facilities with fewer than the minimum requirement for commodes up to the minimum number required.
4/ Percentages do not total 100 percent due to rounding.

(Continued)

Table 9. Comparison of Four-County 1/ Shelter Facility Characteristics by Facility Size (Continued)

		Commodes					Generators	
Building Size	Building Use	Existing Commodes	Facilities with Sufficient Number of Commodes 2/	Percent of Total Facilities with Sufficient Number of Commodes	Additional Commodes Needed 3/	Deficit of Commodes per 1,000 People	Number of Facilities with Generator	Percent of Total Facilities with Generator
20,000 Spaces or more	Residential	0	0	0.00	0	0.0	0	0.00
	Educational	0	0	0.00	0	0.0	0	0.00
	Religious	0	0	0.00	0	0.0	0	0.00
	Government and Public Services	0	0	0.00	0	0.0	0	0.00
	Commercial	29	0	0.00	771	19.3	0	0.00
	Industrial	84	0	0.00	1,334	18.8	0	0.00
	Amusement/ Meeting	0	0	0.00	0	0.0	0	0.00
	Transportation	0	0	0.00	0	0.0	0	0.00
	Miscellaneous	0	0	0.00	0	0.0	0	0.00
	SUBTOTAL	113	0	0.00	2,105	19.0	0	0.00
	TOTAL 4/	9,791	435	100.02	12,581	12.7	35	99.99

involved in preparation for use as a fallout shelter, a large facility should require less effort per space than a small facility because most of the planning will follow the same process regardless of the facility size. Table 9 contains an example that illustrates this point. Buildings with 20,000 spaces or more constitute less than 2 tenths of a percent of the total number of facilities, but contain over 11 percent of the total spaces. Buildings with less than 100 spaces comprise over 18 percent of the total number of facilities, but contain less than 3 percent of the total spaces. Certainly much less planning per space should be required to utilize the large buildings for shelter. Similarly, the logistics of actually loading a large building with people and supplies should be much less involved than trying to route the same people and supplies to many separate small buildings. There seems to be a greater probability of confusion and error if several small buildings are involved rather than one large building. The utilization of a larger building also seems favorable if upgrading for fallout protection is considered. A building with greater floor area than another building will have less perimeter per unit of area (e.g., a doubling of each exterior dimension will quadruple the floor area, other factors being equal). Therefore, a large building should require less earthmoving if earth must be piled to the same height and thickness against all of the exterior walls.

An examination of the relationships of group size and occupant density to the provision of light and ventilation also seems to favor large buildings and displays a case where varying the population density affects the resource requirements of a service. The requirement for lighting is not dependent on the number of shelter occupants. It is instead, a function of the usable floor area, and of the number of rooms in a particular facility. Therefore, increasing the population density does not increase the lighting required, so that fewer resources (particularly power) are required per shelter space. Conversely, decreasing the population density increases the resource requirement per space. In the case of the relationship of group sizes to the provision of light, smaller facilities should tend to have smaller rooms and, consequently, need more lights and more power per shelter space.

Unlike the lighting requirement, the ventilation requirement is directly proportional to the number of occupants in a shelter. Hence,

changing the occupant density has no effect on the resource requirement per space for ventilation. The same reasoning applies to the effect of group size on resource requirements per space. It is likely that more small buildings will require expedient ventilation systems (fans due to inadequate or no existing ventilation system and relatively more Kearney pumps because of smaller rooms with no existing ductwork to distribute ventilation), though the power requirement per space should not be significantly different with various sizes of buildings.

The provision of water presents a situation in which smaller facilities seem to be favored. The survey data in Table 9 pertaining to facilities with water supply indicate that most facilities are supplied with water, regardless of the size of the facility. However, almost 90 percent of the facilities with wells have less than 1,000 spaces. Furthermore, no facility in the survey with 10,000 or more spaces is serviced by a well. Therefore, smaller facilities seem to have a greater likelihood of being served by an uncontaminated source of water.

Since the water supply requirement is directly proportional to the number of occupants in a shelter, the per space resource requirement does not seem to be affected by variations in occupant density. However, a couple of factors are important when evaluating whether it is feasible or desirable to vary the occupant density in a particular facility. First, if the occupant density is to be reduced only in certain facilities, it may be desirable to reduce it in facilities where there is a water supply that is insufficient to supply all of the people that could be accommodated at 10 square feet per person. In this manner, it may be possible to avoid augmenting the water supply in these facilities. The second factor to consider is applicable to the case where the population density needs to be increased. An increase in population density may reduce the amount of usable floor area due to the additional space required for water storage containers. Each facility should be evaluated on an individual basis to ensure that there will be adequate room for water storage containers without causing a further increase in occupant density.

The relationships of group size and occupant density to sewage and solid waste disposal are similar to their relationships to the supply of potable water. The survey data in Table 9 pertaining to commodes indicate

that over 85 percent of the facilities with a sufficient number of commodes have less than 500 spaces and that no facilities with 5,000 or more spaces have a sufficient number of commodes. This fact seems to favor the use of small facilities. If solid waste is to be disposed of in trenches outside of the shelter, again small shelters may be favored because a small facility will probably require more earth per shelter space for fallout upgrading, thus resulting in a relatively larger volume of trenches. The same consideration applies to sewage disposal as to water supply in evaluating the desirability of decreasing the occupant density in particular facilities (i.e., decrease the occupant density in facilities with a shortage of commodes), and the feasibility of increasing the occupant density is affected by the same factor (i.e., increased space requirement for collection and storage containers) as water supply in the cases of both sewage and solid waste disposal.

In summary, if a choice must be made between utilizing large or small facilities, the availability of resources could be a determining factor. Large facilities are generally favored, but the use of smaller facilities might be advantageous if potable water supply or waste disposal are severe problems due to shortages of water, storage containers, commodes, chemical toilets, collection containers, or disinfectants. In general, decreases in occupant density should be implemented in facilities with inadequate existing water supply or sewage disposal systems. Occupant density should be decreased enough so that augmentation of these systems is not necessary in these facilities. Before an increase in occupant density is planned, each facility should be evaluated to ensure that the extra space requirements for water and waste storage do not conflict with the usable floor area needed for the shelter occupants.

VI. DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

One of the chief objectives of this study is to identify differences in building characteristics between small and large facilities that are relevant to the provision of services. As was the case with the large facility study, the limited scope of work under this project constrained the available data to that which could be extracted from existing publications and surveys. The same sources of data were utilized as were used in the large facility study in an effort to derive results that could be relevantly compared. Therefore, the information contained herein is subject to the same caveats and limitations as the information in the large facility study. The most significant of those caveats and limitations to this study are discussed in the succeeding three paragraphs.

Lighting and ventilation requirements of four different building codes are presented to demonstrate consistencies among the codes, not for the purpose of estimating building characteristics in different geographical regions of the country. The information presented should be representative of the building code requirements for lighting and ventilation over the entire country. Of course, a particular building should not be expected to conform exactly to the requirements presented herein. These are only minimum requirements, and they may even be different from those that were in effect at the time and place that a particular building was constructed.

CRP Host Area Facility Listing data from four counties in the United States are represented in the summary of small shelter facility characteristics. These data pertain to the frequency of occurrence of buildings in the different use classes, the nature of the water supply, the number of permanent commodes, and the presence of emergency generators. Because this information was obtained from actual host area buildings, it may be more representative of the characteristics of rural buildings than are the building code requirements for lighting and ventilation. However, the summary of small shelter facility characteristics is derived from a very small sample of the total number of counties in the United States; hence, it may be biased.

In describing the options for providing services, it was found that existing survey data are inadequate for developing detailed alternatives for the provision of lighting, ventilation, water supply, excreta disposal, and solid waste disposal systems. Additional information needed by local planners to develop detailed plans for a specific building includes the following items:

- specifications for existing electrical power distribution systems
- specifications for existing engine-generators, including the type of transfer switch
- specifications for existing mechanical ventilation systems, including the amount of air normally recirculated
- method of water delivery through the existing water supply system (pumped from reservoir, gravity feed from reservoir, etc.)
- well capacity, pump capacity, and the water line size where wells exist
- number of watering points available in the building
- type of sewage disposal system (septic tank, tertiary treatment, etc.)
- capacity of the sewage disposal system
- number and capacity of existing incinerators

There are actually few differences in relevant building characteristics between large and small facilities that can be identified from the available data. It is speculated that small facilities contain smaller rooms, resulting in greater power requirements per space for lighting, and also, that a lower percentage of small facilities than large facilities contains existing air conditioning systems, but these suppositions are unsubstantiated by available data. The four-county host area survey results do indicate that small facilities are more likely to be supplied with water from wells and to contain adequate numbers of commodes for the shelter population. Though these factors seem to favor the use of small facilities over large facilities in host areas (where there is a choice), the use of large facilities is advantageous under most circumstances. The advantages of using large shelters include:

- the lower level of planning effort required per shelter space,
- the more straightforward logistics problem of transporting people and supplies to a smaller number of shelters,
- the lower level of resources per shelter space needed to upgrade the fallout protection in a large shelter.

Small facilities should only be chosen over large facilities in host areas where there are severe shortages of water, storage containers, commodes, chemical toilets, collection containers, or disinfectants.

In a host area with more shelter spaces than potential shelter occupants, decreasing the occupant density in facilities with existing, but inadequate, water supply or sewage disposal systems to a level where no augmentation is needed, is a shelter alternative to consider. This alternative is not desirable if there is a shortage of emergency generators because decreasing the occupant density in a facility increases the lighting power requirement per space. From a provision of services standpoint, occupant density should not be increased without evaluating the amount of usable floor area that is lost due to increased requirements for storage containers for water and waste.

In planning for the crisis utilization of a shelter facility, the existing systems in the facility and availability of resouces in the host area play the major roles in determining methods for augmenting and/or providing services. However, it is important to realize the interrelationships among the different systems in a facility to ensure that they will be compatible. For example, the quantity of water which must be provided is a function of the temperature, which in turn is a function of the volume of ventilation that is delivered. If enough water is provided for cooking and cleaning, then the sewage disposal system must have sufficient capacity to handle this as well as human excreta. Adequate emergency power must be provided to carry the combined load of the lighting and ventilation systems as well as to drive the pump in a facility serviced by a well. Clearly, the system for providing one particular service to a facility must not be developed independently of the other systems.

As in the case of the large shelter facility study, this is not a definitive study on the provision of crisis implemented lighting, ventilation, water supply, sewage disposal and solid waste disposal systems in small shelter facilities. However, taken together, the two studies provide information that should be helpful to local civil preparedness planners in developing a host area shelter plan. Hopefully, they also provide some guidance for future studies into the crisis utilization of existing shelter space.

REFERENCES

1. Wright, M. D., S. B. York, III, R. H. Hill, and J. L. McKnight, Study of Crisis Utilization of Large Shelter Space. Final Report 44U-1340. Research Triangle Institute, Research Triangle Park, North Carolina. August 1977.

2. National Building Code 1976. Engineering and Safety Service, New York, New York. 1976.

3. Standard Building Code 1976 Edition. Southern Building Code Congress International, Inc., Birmingham, Alabama. 1976.

4. Building Code of the City of New York. Van Nostrand Reinhold Company, New York, New York. 1970.

5. Official Building Code of the City of Detroit. Department of Buildings and Safety Engineering, Detroit, Michigan. 1964.

6. 1974 Applications Handbook. American Society of Heating, Refrigeration and Air Conditioning Engineers, New York, New York. 1974.

7. Foget, Carl R., and William H. Van Horn, Availability and Use of Emergency Power Sources in the Early Postattack Period. Final Report URS 710-4, URS Research Company, Burlingame, California. August 1969.

8. Cristy, G. A. and C. H. Kearny, Expedient Shelter Handbook. Final Report ORNL-4941, Oak Ridge National Laboratory, Oak Ridge, Tennessee. August 1974.

9. Martin, Thomas L., Jr., and Donald C. Latham, Strategy for Survival. The University of Arizona Press, Tucson, Arizona. 1963.

10. "What the Planner Needs to Know About the Shelter Environment," Chapter 7 in DCPA Attack Environment Manual. CPG2-1A7, Defense Civil Preparedness Agency, Department of Defense, Washington, D.C. June 1973.

11. Assar, M., Guide to Sanitation in Natural Disasters. World Health Organization, Geneva, Switzerland. 1971.

12. General Industry Standards. OSHA 2206, 29 CFR 1910, OSHA, U.S. Department of Labor. January 1976.

13. "Fallout Shelter Water Requirements," Part D, Chapter 2, Appendix 4, in Federal Civil Defense Guide. Office of Civil Defense, Department of Defense, Washington, D.C. July 1965.

14. "Standard Man," in Radiological Health Handbook. Revised edition, Bureau of Radiological Health and the Training Institute, Consumer Protection and Environmental Health Services, Public Health Service, U.S. Department of Health, Education and Welfare, Rockville, Maryland. January 1970.

15. Salvato, Joseph A., Jr., Environmental Engineering and Sanitation. 2nd ed., Wiley-Interscience, New York, New York. 1972.

Appendix A

ELECTRICAL POWER FOR CRISIS ILLUMINATION AND VENTILATION IN EXISTING BUILDINGS

Appendix A

ELECTRICAL POWER FOR CRISIS ILLUMINATION AND VENTILATION IN EXISTING BUILDINGS

The purpose of this appendix is to show how the electrical systems of an existing building can be adapted so that a small building can be used as a civil defense fallout shelter. In previous work [Ref. 1], it has been demonstrated that a mine with a drift entrance can be illuminated and ventilated adequately for use as a fallout shelter. Later, the techniques used in the illumination and ventilation of a mine were applied to the illumination and ventilation of large existing buildings [Ref. 2]. This study applies the techniques that were developed for the conversion of large buildings into fallout shelters to the conversion of small buildings into fallout shelters.

Electrical power is provided in most small buildings at the service entrance either as a three-phase, 240-volt or 208-volt circuit, or as a single-phase, 240-volt circuit. No other circuits will be considered in this appendix. Information on larger distribution systems is presented in the <u>Study of Crisis Utilization of Large Shelter Space</u> [Ref. 2].

A. The Electrical Systems of Existing Buildings

The electrical distribution system of most existing, small commercial buildings usually is a 208/120-volt, three-phase, wye-connected, four-wire system; a 240/120-volt, three-phase, open delta-connected, four-wire system; or a 240/120-volt, single-phase, three-wire system. A three-phase electrical distribution system for a small commercial building is illustrated in Figure A-1. Motor loads are connected to the three-phase conductors, and 120-volt, single-phase lighting load and convenience outlet circuits are connected between a phase conductor and the neutral conductor. If the electrical service is a 208/120-volt, wye-connected circuit, then the single-phase loads are distributed among the three-phase conductors to keep the supply current approximately the same in each phase conductor. If the electrical service is a 240/120-volt, open delta-connected circuit, then the 120-volt, single-phase loads are connected between the neutral conductor (which is connected to the center-tap between two-phase conductors) and

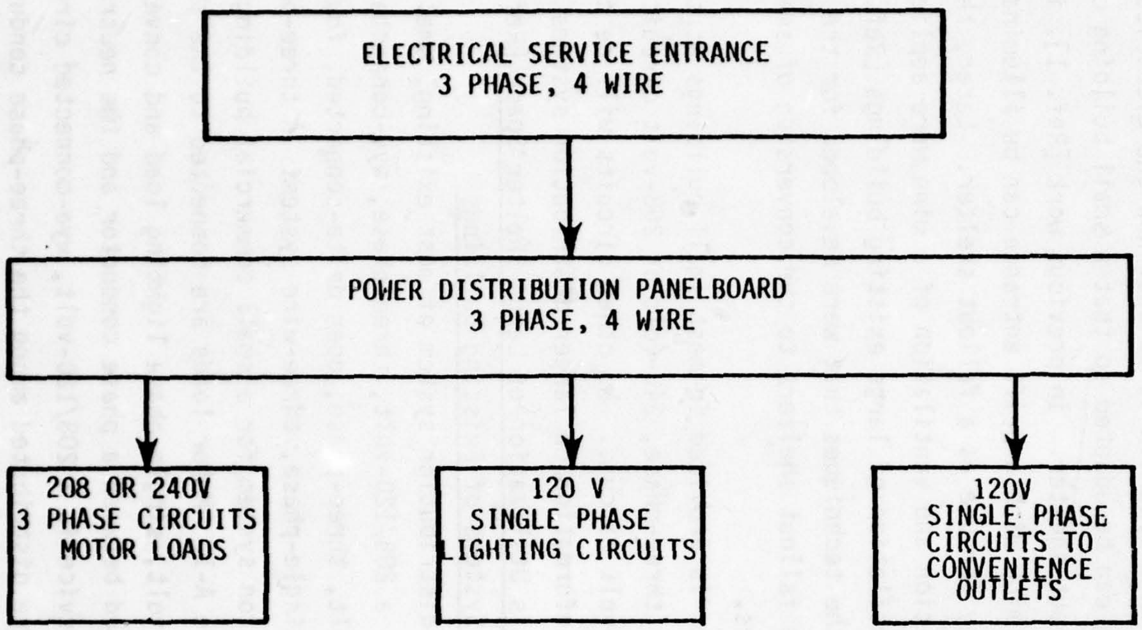


Figure A-1. Flow Chart of a Representative Three-Phase Electrical Distribution System in a Small Commercial Building. Each three-phase motor load would have a separate circuit. Lighting and convenience outlet circuits usually are rated at 15 amperes and connected with a maximum load of 1000 watts.

either adjacent phase conductor. Very small buildings may have a single-phase 240-volt electrical service entrance with the 120-volt loads connected between the neutral conductor and either phase conductor as in the open delta connection.

Most older commercial buildings have a 240/120-volt, three-phase, open delta-connected service entrance because only two single-phase transformers are needed to transform from the distribution voltage to the service entrance voltage. These transformer banks are usually mounted on poles because the two transformers cannot be of the same size. In contrast, pad-mounted transformers always have a 208/120-volt secondary. The trend today is to use underground wiring, pad-mounted transformers, and 208/120-volt service entrances.

A standby engine-generator in an existing building is connected to the electrical distribution system by a transfer switch. The transfer switch can be either of the manual or the automatic type. The automatic transfer switch automatically starts the engine-generator and transfers selected portions of the building's load to the standby engine-generator. Usually, automatic transfer switches are installed in electrical distribution systems that are operated by untrained personnel, and the electrical circuits are connected so that it is impossible to damage the engine-generator through improper operation.

In buildings that are maintained by trained personnel, such as heating plants or factories, manual transfer switches may be used. Because standby engine-generators seldom can handle the capacity of an entire plant, the operating personnel usually must disconnect part of the load in a building before the manual transfer switch can be used to connect the building's load to the engine-generator. The use of a manual transfer switch provides flexibility in the selection of electrical loads.

If a building contains a stationary standby engine-generator, a survey must be made to determine if the capacity of the engine-generator is adequate to provide power for the existing illumination and ventilation systems. If the capacity of the engine-generator is adequate for all anticipated loads, then the system can be operated without modification. If the capacity is inadequate, then enough loads must be disconnected so that the generator cannot be overloaded. Disconnections can be made either by detaching electrical cables and taping bare conductors or by setting circuit breakers in the "off" position and applying tape or warning tags.

B. Temporary Connection of an Engine-Generator to the Distribution System of a Building

When no provision has been made for connecting a standby engine-generator to the distribution system, a procedure of three steps must be followed. First, the load must be analyzed. Second, the available engine-generators must be classified. Third, the optimum method of connecting the engine-generators to the load must be determined.

The analysis of the load must be based on the devices that are expected to be operated during the crisis situation. These devices will be primarily lights and fan motors as well as pumps in facilities with wells. The operating voltage and power consumption must be determined from the nameplate of each device. In recording the power consumption of a device, the wattage of each lamp and the full load current of each motor will usually be easiest to determine. The power consumption of the ballasts of fluorescent lamps or metal vapor lamps must not be neglected.

After the loads are classified, the existing distribution system must be charted. A single-line diagram of the existing distribution system should be made as an aid in planning the emergency system. Disconnection points, including circuit breakers, fuses, and disconnect switches should be shown.

The engine-generators that are available must be classified according to voltage, phase, and capacity. The engine-generators that are most readily available probably will be small single-phase, 120-volt or 240/120-volt, portable units with load capacities not greater than 5,000 watts.

The larger, three-phase engine-generators may be mounted on a trailer. Therefore, they may not be usable unless they can be moved inside the fallout shelter. Occasionally, small three-phase engine-generators of 5,000- to 20,000-watt capacity are used, although this size of engine-generator is probably too large to be efficiently used in a small fallout shelter.

Three-phase generators are usually capable of operating either at 480/277 volts or at 208/120 volts. Generators operating in the lower voltage range can be adjusted and connected for operation at 208/120 volts or at 240/120 volts. Some generators can be connected to operate at any of the above voltages.

The method used to connect the engine-generators that are available will depend upon the loads to be served and the type of distribution

system available. Six special cases can be used to illustrate many of the possible methods of connection. These six cases are illustrated in Figures A-2 through A-7.

The cases illustrated in Figures A-2 and A-3 are where the engine-generators and loads are compatible in voltage and phase connection. In Figure A-2, the transfer switch connects the portion of the electrical load needed for operation during a failure of the normal power supply to the standby engine-generator. In Figure A-3, the emergency load is disconnected from the distribution panelboard and reconnected to the standby engine-generator. In Figure A-4, a situation similar to Figure A-3 occurs, but here two separate loads are disconnected from the panelboard and separately reconnected to two engine-generators.

Figures A-5 and A-6 illustrate a method for supplying emergency power when no three-phase generator is available. The three-phase service entrance and all three-phase loads are disconnected; no power can be provided to these loads. Each engine-generator is connected to one or more phase conductors as shown in Figures A-5 and A-6. Single-phase, 120-volt loads can be powered from a 120-volt standby engine-generator.

Figure A-7 illustrates the unlikely case where two 120-volt generators must be used to supply power to a 240-volt, single-phase panelboard. In this situation, no 240-volt load circuit can be operated because the proper phase synchronization would not exist between the two generators.

Safe and effective operation of electrical equipment is difficult to achieve in a crisis situation when temporary modification of the existing system is required. Access to all electrical equipment should be restricted to trained personnel with a knowledge of the modifications. Modifications should be labeled. As a minimum precaution, tape should be placed over a circuit breaker when it is not to be operated, and the operating arm of a disconnect switch should be held open with wire if a lock is not available.

References

1. M. D. Wright, E. L. Hill, J. S. McKnight, S. B. York, III, Mine Lighting and Ventilation in Crises, Final Report 43U-982-1. Research Triangle Institute: Research Triangle Park, North Carolina. October 1975.

2. M. D. Wright, S. B. York, III, R. H.Hill, J. S. McKnight, Study of Crisis Utilization of Large Shelter Space, Final Report 44U-1340. Research Triangle Institute: Research Triangle Park, North Carolina. August 1977.

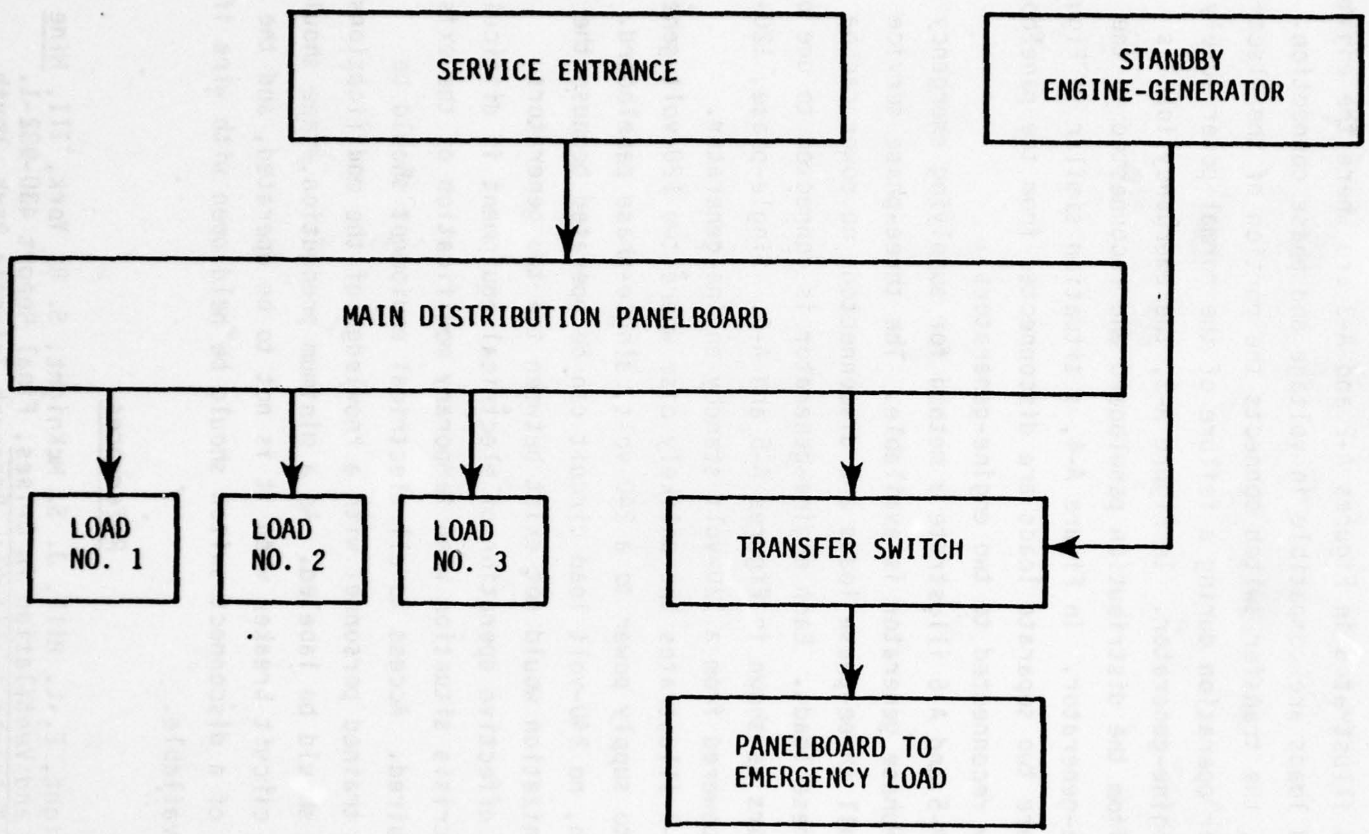
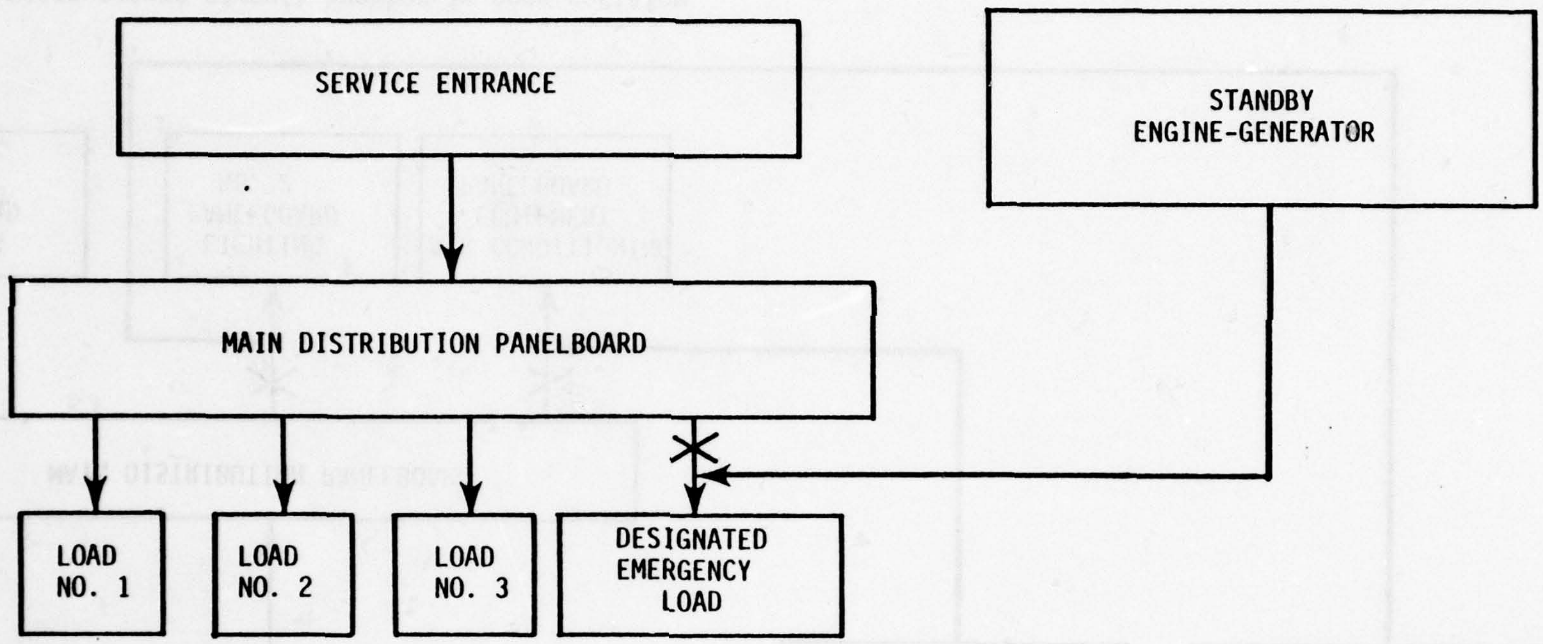
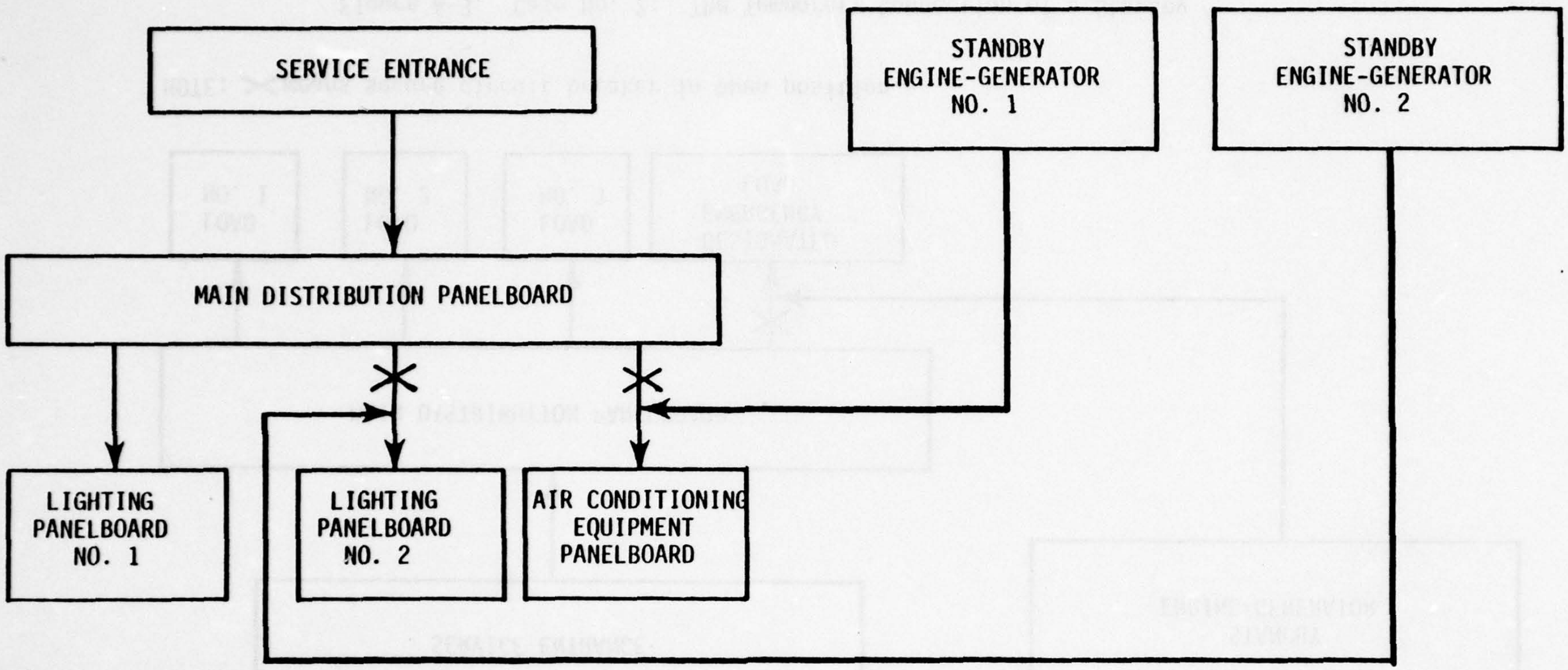


Figure A-2. Case No. 1: The Permanent Connection of a Standby Engine-Generator



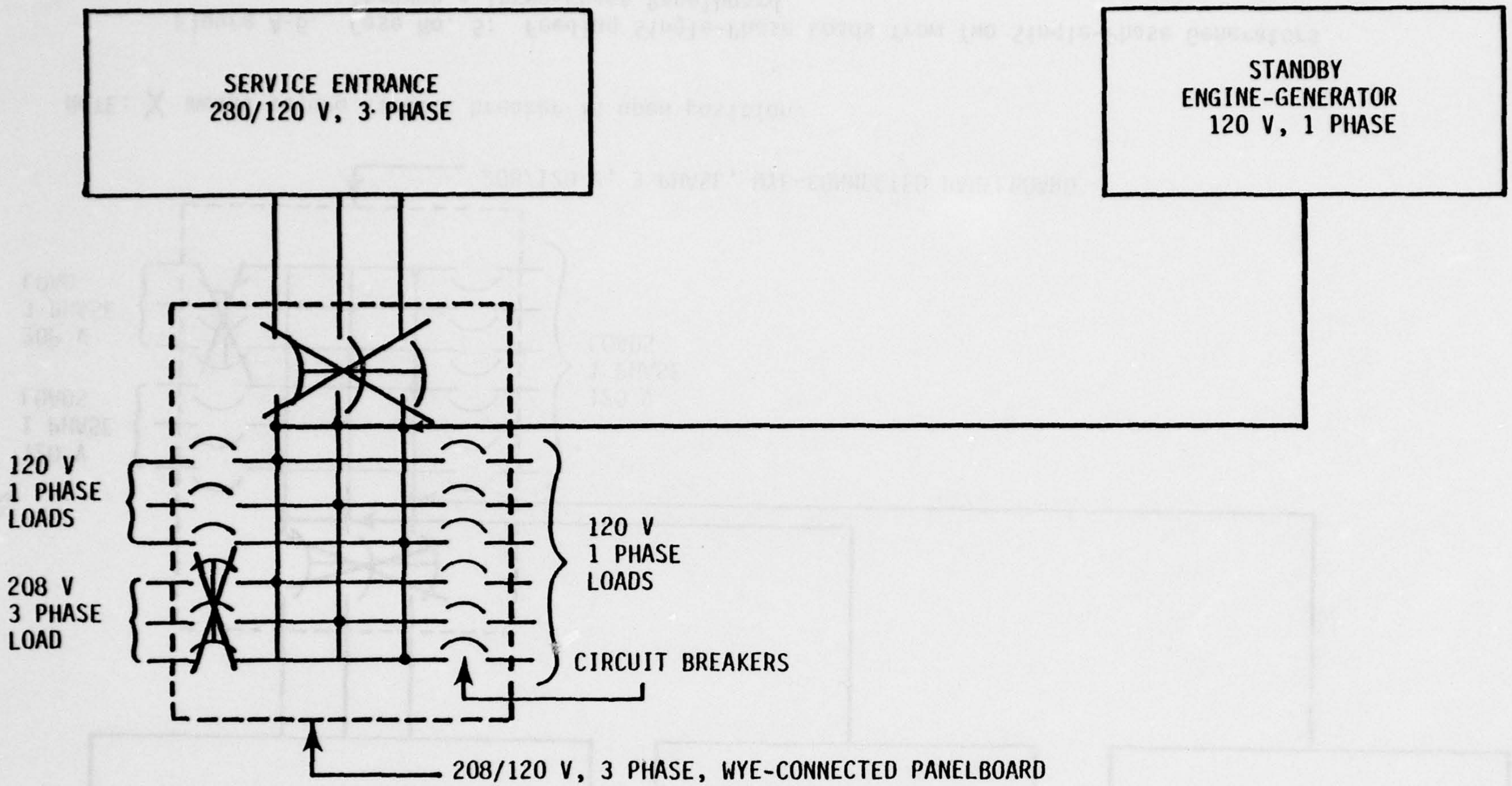
NOTE: X means secure circuit breaker in open position.

Figure A-3. Case No. 2: The Temporary Connection of a Standby Engine-Generator Set



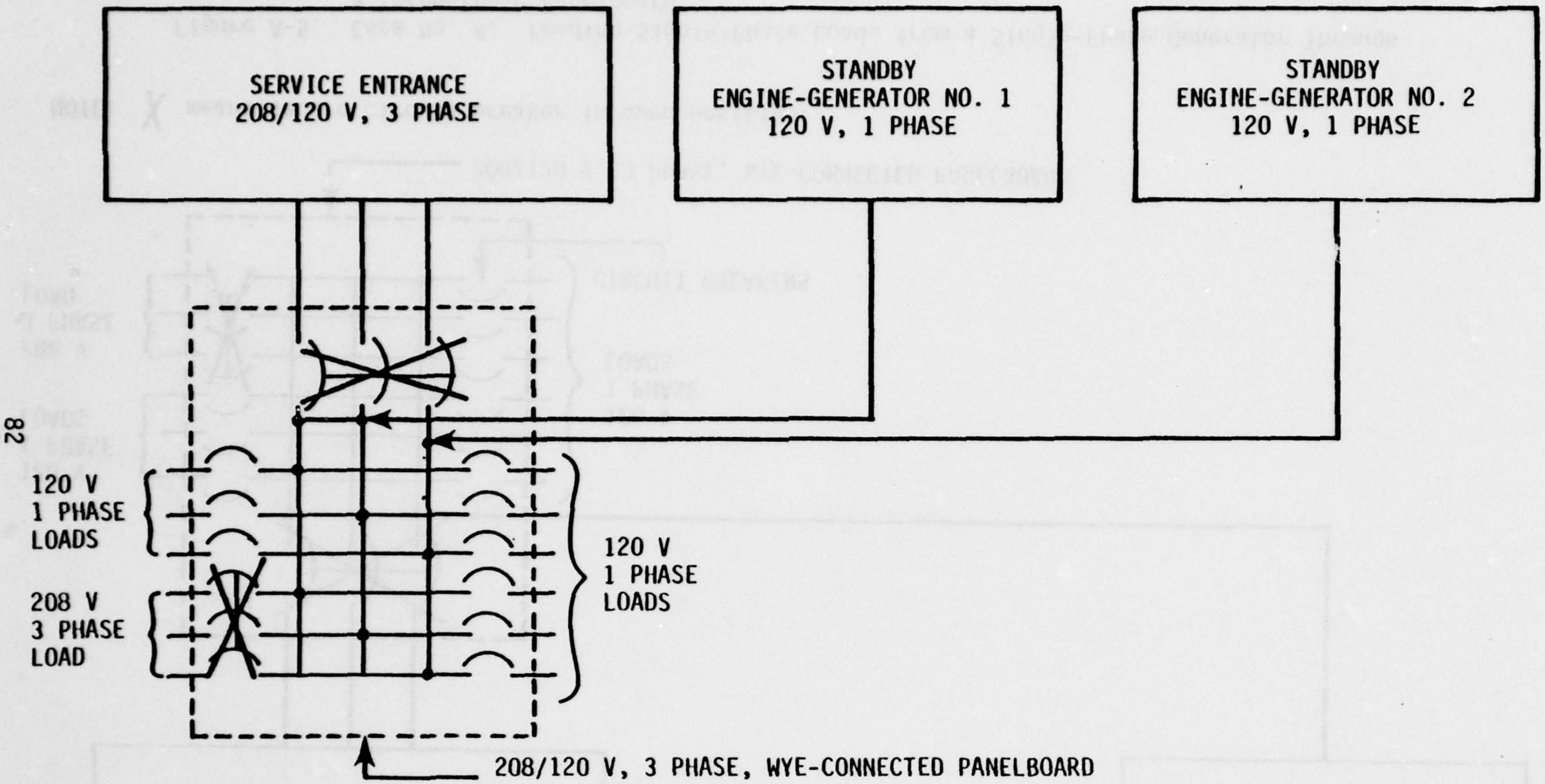
NOTE: ✕ means secure circuit breaker in open position.

Figure A-4. Case No. 3: The Temporary Connection of Two Standby Engine-Generator Sets



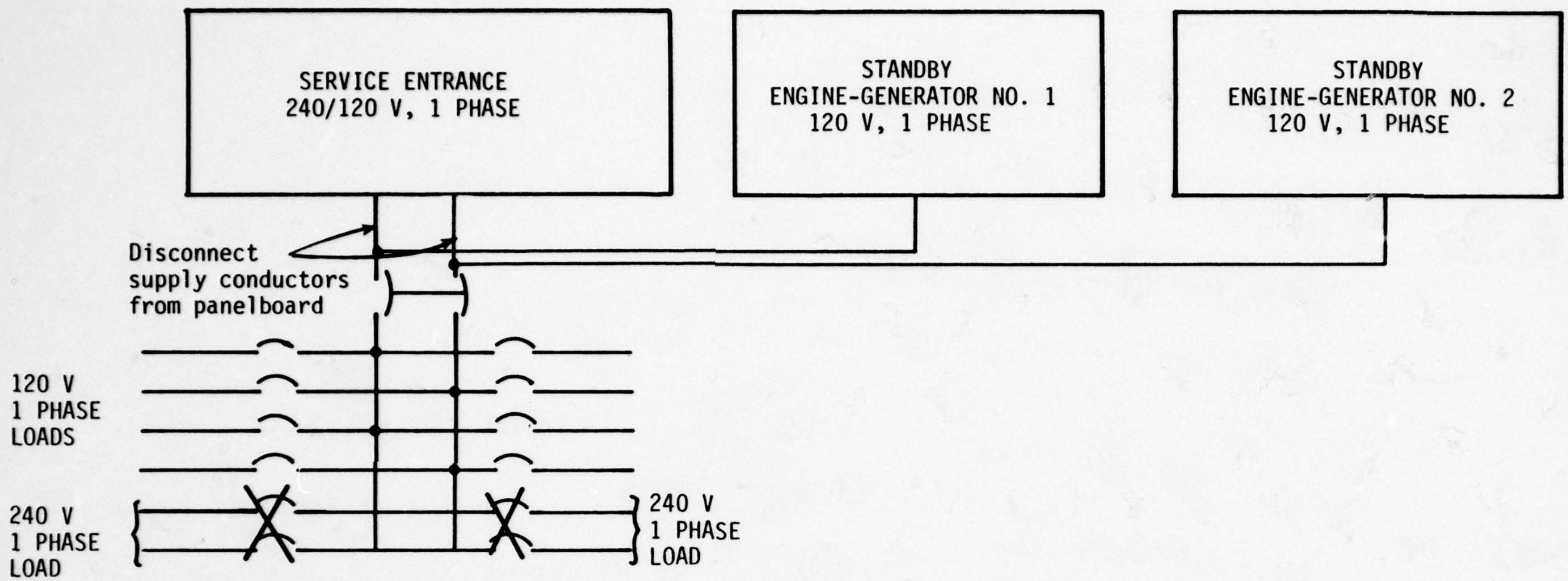
NOTE: X means secure circuit breaker in open position.

Figure A-5. Case No. 4: Feeding Single-Phase Loads from a Single-Phase Generator Through a Three-Phase Panelboard



NOTE: X means secure circuit breaker in open position.

Figure A-6. Case No. 5: Feeding Single-Phase Loads from Two Single-Phase Generators Through a Three-Phase Panelboard



NOTE: X means secure circuit breaker in open position.

Figure A-7. Case No. 6: Feeding a 240/120-Volt Single-Phase Panelboard from a 240/120-Volt Single-Phase Engine-Generator. If only a 120-Volt generator is available, each phase conductor of the panelboard can be connected to a separate generator; however, 240-volt loads cannot be driven by separate 120-volt generators in this configuration.

Appendix B

HOST AREA SHELTER SERVICES

Appendix B

HOST AREA SHELTER SERVICES

This appendix contains three examples of the use of the guidelines established in this report to formulate lighting, ventilation, water supply, sewage disposal, and solid waste disposal plans. Each building floor plan is derived from a building surveyed in the CRP Host Areas Facility Survey, with additions and modifications made for the sake of the example. An example of one building from each of three different use classes: commercial, government and public services, and educational is included. These were the three most prevalent use classes found in the four-county sample from the CRP Host Areas Facility Listing.

Service requirements in the examples are calculated for the maximum in-shelter period of 14 days. In most cases, the stay time will be much less than this (an average of about seven days); however, the examples are used to illustrate the most severe requirements.

I. EXAMPLE NUMBER 1
(NEWPORT PLUMBING SUPPLY)

A. General

Newport Plumbing Supply is a wholesale distributor of plumbing products that is located in a rural midwestern community. It consists of a showroom which also serves as storage for supplies, an adjoining storage room, and a small office. Figure B-1 presents a floor plan of the facility.

There are 2,120 square feet of floor area usable for shelter in Newport Plumbing Supply. Therefore, at 10 square feet per person, it will accommodate 212 shelter occupants in a crisis situation. The building is served by an artificial lighting system, but it does not have a mechanical ventilation system. The exterior wall aperture area totals 319 square feet, excluding doorways. The building contains one restroom with two toilets and one faucet. The only other watering point is a water fountain which is situated in the back of the showroom. Garbage is collected twice weekly by a municipal service.

B. Lighting

The artificial lighting system which illuminates Newport Plumbing Supply is more than adequate for the building's use as a fallout shelter, particularly in the showroom area. Because it is a relatively large open area, only about 3 percent of the system's total capacity is needed in the showroom, and about 25 percent of the total capacity in the storage room. Emergency power is not available on site, so portable engine-generators of appropriate voltage and capacity must be located and arrangements made for their use. An experienced electrician or electrical engineer should determine the power and voltage required. The ventilation system must also be considered in this determination.

C. Ventilaton

Newport Plumbing Supply can accommodate 212 shelter occupants and is located in a county having a zonal ventilation requirement of 10 cfm per occupant to maintain the effective temperature at a maximum of 82^0F with a 90 percent reliability. Therefore, the design capacity of the ventilation system should be 2,120 cfm (212 shelter occupants x 10 cfm/shelter occupant). From one to three wall or pedestal fans of the type that is available in retail stores will provide this volume of air flow.

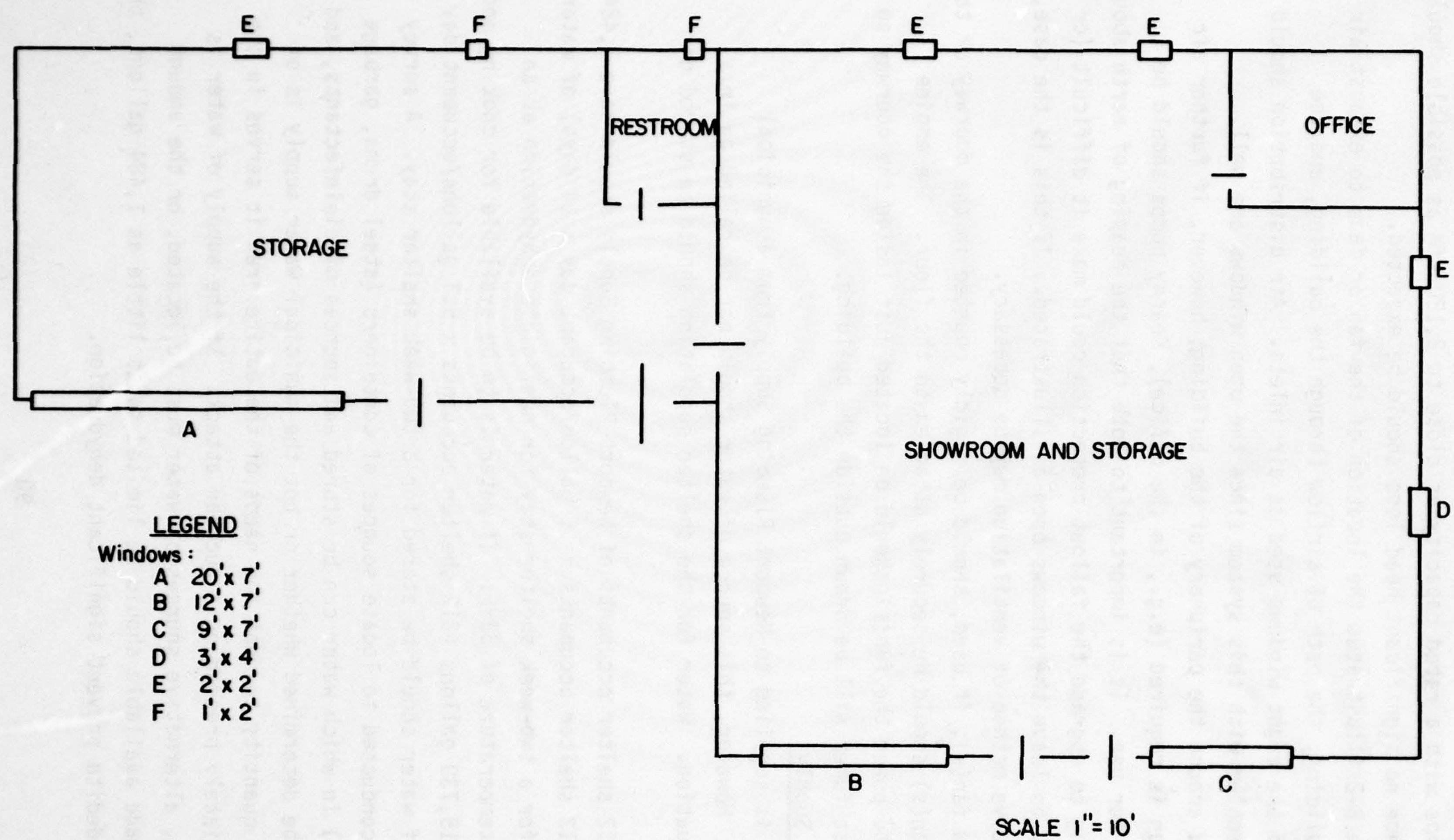


Figure B-1. Floor Plan for Newport Plumbing Supply.

Ideally, fans with a rated capacity as close to 2,120 cfm as possible should be used since no significant head loss should be expected.

Figure B-2 illustrates the location of the fan or fans to exhaust air from the building, the path of airflow through the building, and the location of the eight windows used as air inlets. Air distribution should not be a problem with this system since the open windows are well distributed around the periphery of the building; however, if further air distribution is required (e.g., in the office), Kearny pumps should be considered for use. It is important to note that the heaping of earth about the building to upgrade the fallout protection could make it difficult (or impossible) to leave the windows open as illustrated. If this is the case, an alternative method of ventilation may be necessary.

Window fan(s), if used, should be rigidly mounted in the doorway or the pedestal fan(s) should be securely attached to the floor. The engine generator to power the fan(s) should be located just inside the doorway so that exhaust fumes will be drawn outside the building.

D. Water Supply

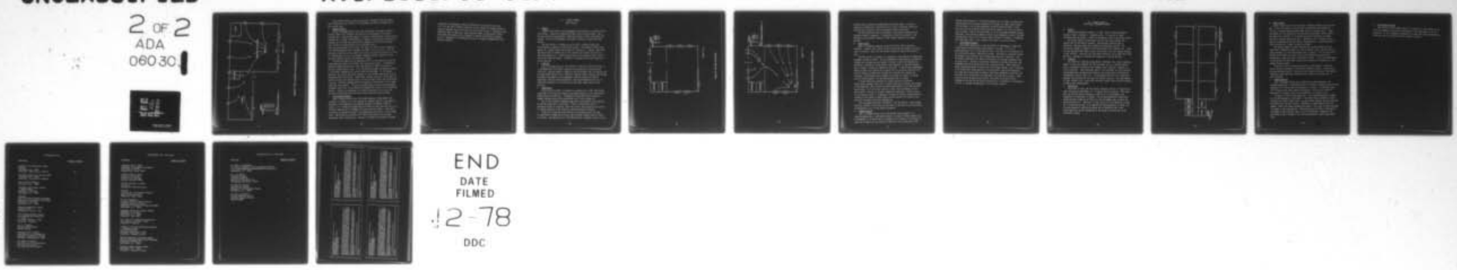
Water is supplied to Newport Plumbing Supply from a municipal reservoir. However, this source of water should not be relied on in a crisis situation. Water for the shelter population should be stored on site.

The 212 shelter occupants of Newport Plumbing Supply should have 1,484 gallons (212 shelter occupants x .5 gallon/occupant day x 14 days) of water available for a two-week shelter stay for negligible dehydration at an effective temperature of 82^{0}F. If water is to be available for cooking and cleaning, 15,730 gallons (212 shelter occupants x 5.3 gallons/occupant day x 14 days) of water should be stored for a two-week shelter stay. A survey should be conducted to locate sources of containers (steel drums, garbage cans, etc.) in which water can be stored and sources of disinfectants, and it should be determined whether or not the municipal water supply is of sufficient quantity to meet the needs of the entire area it serves in the days immediately preceeding a nuclear attack. If the supply of water is inadequate, alternative sources of water must be located, or the amount of water made available should be limited to as little as 1,484 gallons, the amount needed to prevent significant dehydration.

AD-A060 301 RESEARCH TRIANGLE INST RESEARCH TRIANGLE PARK N C APP--ETC F/G 18/6
STUDY OF CRISIS UTILIZATION OF SMALL SHELTER SPACE.(U)
AUG 78 S B YORK, J S MCKNIGHT DCPA01-77-C-0232

UNCLASSIFIED RTI/1533/00-05F NL

2 OF 2
ADA
060301



END
DATE
FILMED
12-78
DDC

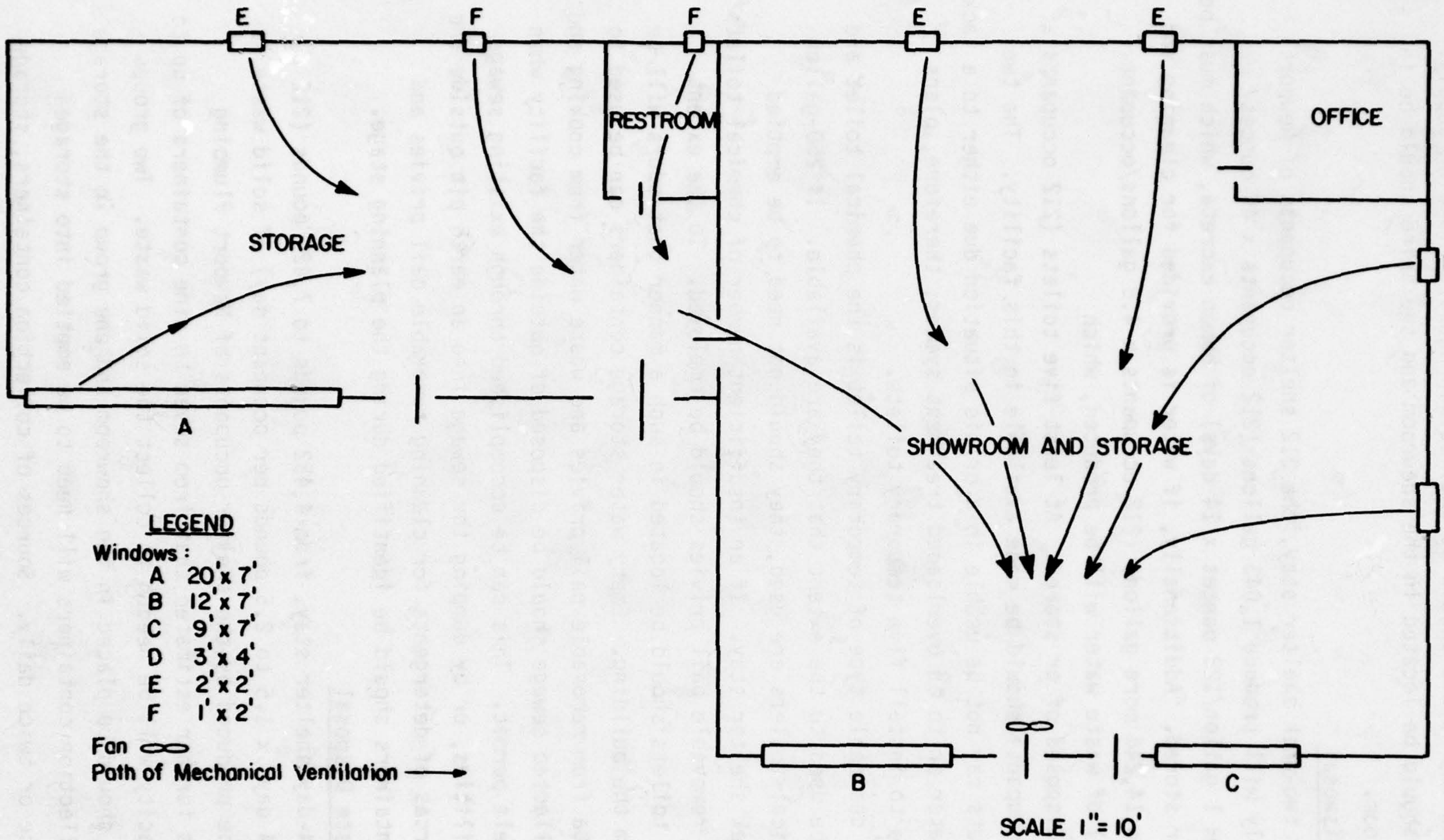


Figure B-2. Flow of Ventilation Through Newport Plumbing.

Three watering points should be provided in Newport Plumbing Supply. Two of these should be located in the showroom and the third should be in the storage room.

E. Sewage Disposal

During a two-week shelter stay, the 212 shelter occupants of Newport Plumbing Supply will produce 1,043 gallons (212 occupants x 45 ounces/ occupant day x 1 gallon/128 ounces x 14 days) of human excreta, which must be disposed of or stored. Additionally, if water is provided for cleaning and cooking, up to 14,246 more gallons (212 occupants x 4.8 gallons/occupant day x 14 days) of waste water will be produced, which also must be disposed of or stored. At least five toilets (212 occupants x .02 toilets/occupant) should be made available in this facility. The two existing toilets may not be usable in a crisis situation due either to a lack of flushing water or to an overloaded treatment system; therefore, plans should be made to install five temporary toilets.

The most desirable type of temporary toilet is the chemical toilet and these should be used to the extent that they are available. If 250-gallon capacity chemical-toilets are used, they should not need to be emptied during a 2-week shelter stay. If an insufficient number of chemical toilets is available, removable pail privies should be employed. To the extent possible, the toilets should be located in such a manner that odors will be exhausted from the building. Empty water storage containers can be used to collect excreta from removable pail privies and waste water from cooking and cleaning. Collected sewage should be disposed of outside the facility when radiation levels permit. This can be accomplished through existing sewage treatment facilities, or by dumping the sewage into an earth pit outside the shelter. Sources of detergents for cleaning removable pail privies and collection containers should be identified during the planning stage.

F. Solid Waste Disposal

Over a 14-day shelter stay, from 4,452 pounds to 7,420 pounds (212 occupants x 14 days x 1.5 to 2.5 pounds per occupant day) of solid waste is estimated to be produced by the shelter occupants of Newport Plumbing Supply. It is further estimated that from seven to nine containers of up to 26-gallon capacity will be needed to collect the solid waste. Two groups of containers should be placed in the showroom and one group in the storage room. The collection containers will need to be emptied into storage containers once or twice daily. Sources of collection containers, storage

containers and detergents should be identified in the planning period. If all of the water storage containers are not needed for sewage storage as they are emptied, they can be used for solid waste storage. Otherwise, more containers must be supplied. When radiation drops to permissible levels, the stored solid waste can be disposed of outside the building, through burial in trenches or incineration on site, or through transportation to a sanitary landfill.

II. EXAMPLE NUMBER 2
(POST OFFICE)

A. General

A small rural town in the southwestern United States is served by this Post Office. Figure B-3 presents the floor plan of the building. The facility contains approximately 1,400 square feet of floor area usable for shelter. This will accommodate 140 people, allowing 10 square feet per person.

The Post Office is lighted by an artificial lighting system and ventilated by a mechanical ventilation system. The mechanical ventilation system is a closed system and delivers no outside air. However, there are 396 square feet of window area in the exterior walls which can serve to admit and exhaust air. The building contains two restrooms with a total of two toilets and two faucets. Garbage is collected three times weekly by a private service.

B. Lighting

Due to the open nature of the interior of the Post Office building, it is estimated that only about 3 percent of the capacity of the existing artificial lighting system is needed to provide enough light for shelter use. An experienced electrician or electrical engineer should evaluate the voltage and power requirements of the emergency lighting system and identify compatible, portable engine-generators. The engine-generators must be of sufficient capacity to also satisfy any additional power needs in the facility.

C. Ventilation

Since the Post Office is located in a county with a zonal ventilation requirement of 30 cfm per occupant, the design capacity of the ventilation system should be 4,200 cfm. An expedient forced ventilation system is needed, because the existing system does not deliver outside air.

Two to five window or pedestal-type fans are estimated to be required to deliver 4,200 cfm of ventilation. Since no significant loss of efficiency should be incurred, fans with a total rated capacity as close to the design capacity of the system as possible should be located.

Figure B-4 illustrates the location of the exhaust fans, the path of ventilation through the building, and the eight windows used for fresh air inlets. Any additional air distribution that is needed, such as to the

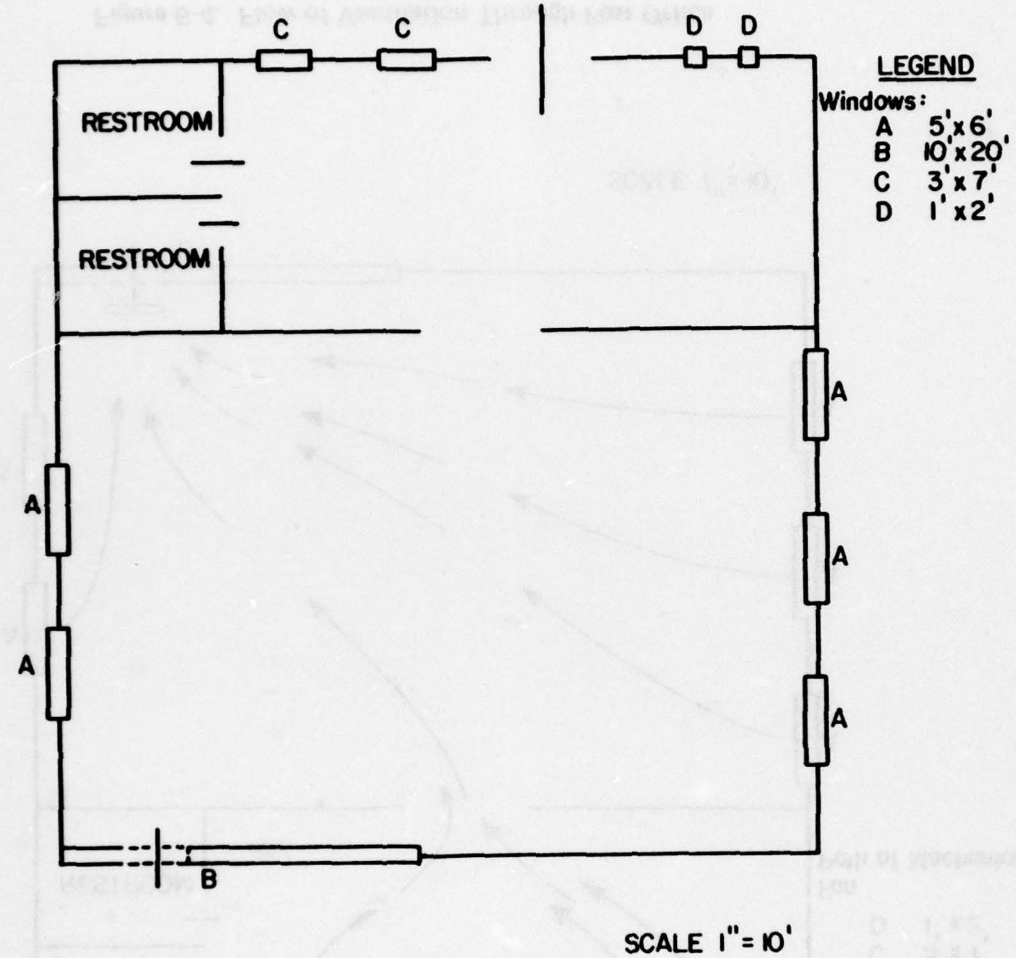


Figure B-3. Floor Plan of Post Office.

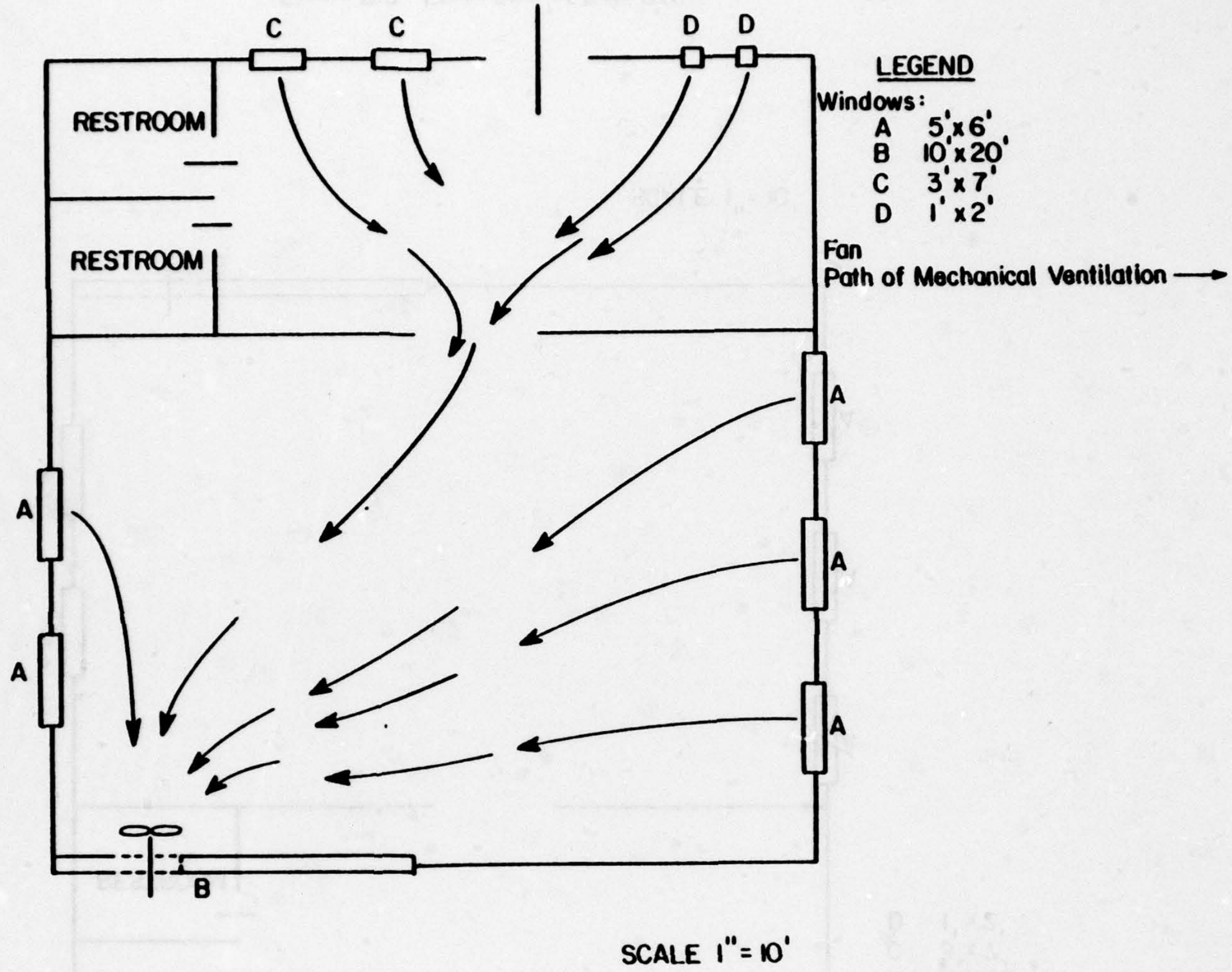


Figure B-4. Flow of Ventilation Through Post Office

restroom areas, should be accomplished with Kearny pumps. It may be necessary to modify this ventilation plan if the illustrated inlets and exhaust must be closed to provide adequate fallout protection.

The fans should be securely anchored in the exhaust doorway and an adjacent window if necessary. The generators should be located in the proximity of the exhaust doorway so that exhaust fumes will be drawn outside.

D. Water Supply

Water is presently supplied to the Post Office from a municipal reservoir. However, this source of water should not be counted on during a crisis situation. Water for the shelter population should be stored on site.

The Post Office is located in a geographic region where the temperature frequently climbs to 100^{0}F. At this temperature, approximately two gallons of water per occupant day are needed to prevent significant dehydration. Therefore, a minimum of 3,920 gallons (140 occupants x 2 gallons/occupant day x 14 days) of water are needed for drinking. If the maximum recommended amount of water (5.3 gallons per occupant day) is provided, there will be only 3.3 gallons of water per occupant day available for cooking and cleaning. The storage capacity needed to provide this amount is 10,388 gallons (140 occupants x 5.3 gallons/occupant day x 14 days).

A survey should be conducted to locate sources of containers (steel drums, garbage cans, etc.) in which water can be stored, and sources of disinfectants, and it should be determined whether or not the municipal water supply is of sufficient quantity to meet the requirements of the entire area it serves in the days immediately preceding a nuclear attack. If the supply of water is inadequate, alternative sources of water must be located, or the amount of water made available should be limited to that which will prevent significant dehydration.

Only two watering points are needed in the Post Office. One of these should be located in the front and the other in the back of the building to be convenient to all of the shelter occupants.

E. Sewage Disposal

Over a two-week shelter stay, 689 gallons (140 occupants x 45 ounces/occupant day x 1 gallon/128 ounces x 14 days) of human excreta will be produced, all of which must be disposed of or stored. If 5.3 gallons of water per occupant day are supplied, there will be an additional 6,468

gallons (140 occupants x 3.3 gallons/occupant day x 14 days) of waste water produced which must also be disposed of or stored. At least three toilets (140 occupants x .02 toilets/occupant) should be made available in this facility. The two existing toilets may not be usable in a crisis situation due to either a lack of flushing water or to an overloaded treatment system; therefore, plans should be made to install three temporary toilets. The same considerations apply in this case as were discussed in Example 1, therefore, the guidelines given in that example also apply to the Post Office.

F. Solid Waste Disposal

Solid waste production in the Post Office is estimated to range from 2,940 pounds to 4,900 pounds (140 occupants x 14 days x 1.5 to 2.5 pounds/occupant) for a 14-day shelter stay. From four to six containers of up to 26-gallon capacity should be provided. One group of containers should be located in the front of the building and one group in the back. The collection containers will need to be emptied into storage containers once or twice daily. Sources of collection containers, storage containers, and detergents should be identified in the planning period. There should be water storage containers available for solid waste storage. This is because of the relatively large quantity of drinking water (two gallons/occupant day) that must be provided to prevent significant dehydration and that will be given off as perspiration and removed by the ventilation system. When radiation drops to permissible levels, the stored solid waste can be disposed of outside the building, through burial in trenches or incineration on site, or through transportation to a sanitary landfill.

III. EXAMPLE NUMBER 3
(PINE FOREST ELEMENTARY SCHOOL)

A. General

Pine Forest Elementary School is a rural school containing grades 1 through 6 that is located in a western state. It consists of eight classrooms and two offices. Figure B-5 presents a floor plan of the school.

The school contains 9,240 square feet of floor area suitable for shelter use (or 924 shelter spaces). The building currently has an artificial lighting system and a mechanical ventilation system. The ventilation system is capable of delivering 9,000 cfm of outside air. There are two restrooms with eight toilets, two urinals, and four faucets located in the facility. There are also two water fountains; one at each end of the building. Garbage is collected twice weekly by a private service.

B. Lighting

The artificial lighting system which illuminates Pine Forest Elementary School is more than adequate for the building's use as a fallout shelter. Only an estimated 5 percent of the system's total capacity is needed in a crisis situation. Since emergency power is not available on site, portable engine-generators of appropriate capacity and voltage must be located and arrangements made for their use. An experienced electrician or electrical engineer should determine the power and voltage required. The requirements of other systems (e.g., ventilation and water supply) must also be evaluated in making this determination.

C. Ventilation

The county in which the Pine Forest Elementary School is located has a zonal ventilation requirement of 7.5 cfm per shelter occupant. This means that for the 924 shelter occupants, 6,930 cfm (7.5 cfm/ccupant x 924 occupants) of ventilation is needed. The existing mechanical ventilation system delivers 9,000 cfm of fresh air with the damper open to admit 100 percent outside air. Therefore, in this case, it is not necessary to plan for a ventilation system, if an appropriate engine-generator to power the existing mechanical ventilation system can be identified and if the engine-generator can be transported to the school and connected to the ventilation system.

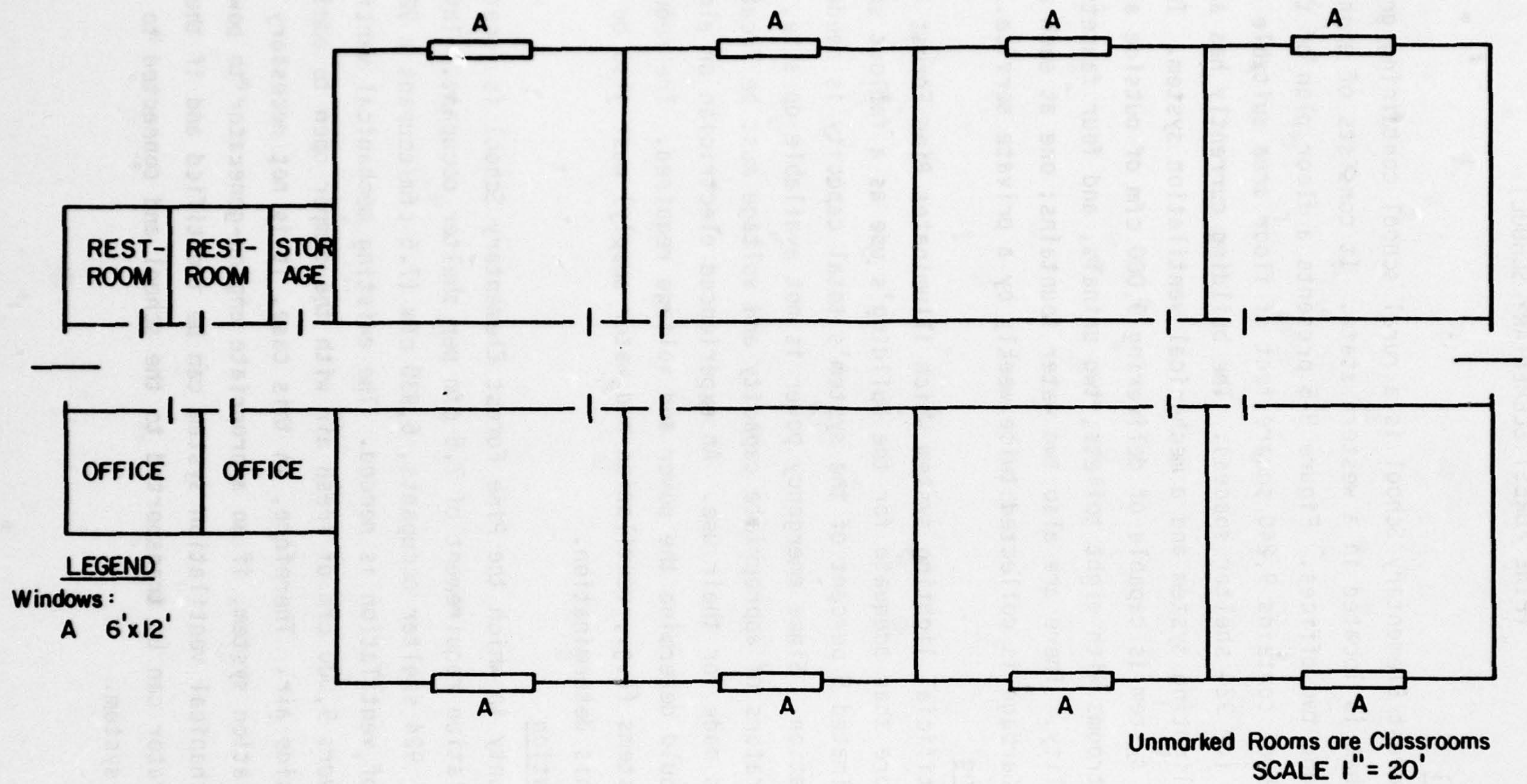


Figure B-5. Floor Plan of Pine Forest Elementary School.

D. Water Supply

Water is supplied to the Pine Forest Elementary School from a private well. Since this source is on-site and is protected from radioactive fallout, it should provide potable water during a nuclear crisis. (Note that power will be required to run the pump to draw water from the well). The capacity of the well is 15 gallons per minute and there are 5,000 gallons of storage capacity on site. Therefore, over a two-week period, there are potentially 307,400 gallons (5,000 gallons + 15 gallons/minute x 20,160 minutes per 14 days) of water available.

The maximum amount of water required for the 924 occupants of the Pine Forest Elementary School for a 14-day shelter stay is 68,561 gallons (924 occupants x 5.3 gallons/occupant day x 14 days). This is just over 22 percent of the amount of water that can be supplied by the well and, consequently, there should be no shortage of water. In this building there is the possibility that water usage may be limited by the capacity of the sewage disposal system.

Using the ratio of one watering point per 100 people, 10 watering points should be provided in Pine Forest Elementary School. There are six existing watering points in the school, but these are not well distributed. Therefore, eight additional watering points should be provided; one in each classroom.

E. Sewage Disposal

Over a two-week shelter stay, 4,548 gallons (924 occupants x 45 ounces/occupant day x 1 gallon/128 ounces x 14 days) of human excreta will be produced, all of which must be disposed of or stored. In addition, there will be waste water from cooking and cleaning. This can be limited if necessary to an amount that can be disposed of or stored on site.

At least 19 toilets (924 occupants x .02 toilets/occupant) are needed for the 924 occupants of the school. The eight toilets presently in the building will remain usable after a nuclear attack because they are supplied with water from the well on-site. Therefore, 11 additional toilets are needed. Again, the same considerations apply in this case as were discussed in Example I with one addition. Precautions must be taken in disposing of the sewage so that the well water is not contaminated. Otherwise, the guidelines given in Example 1 for providing expedient toilets apply here also.

F. Solid Waste Disposal

The problem of solid waste disposal is identical to the problem in the first two examples and should be approached in the same manner, with one exception. It will probably be necessary to locate more storage containers, since none will be available from the storage of water.

DISTRIBUTION LIST

Addresses:	Number of Copies
Defense Civil Preparedness Agency Research Washington, D.C. 20301 Attention: Administrative Officer	50
Assistant Secretary of the Army (R&D) Washington, D.C. 20301 Attention: Assistant for Research	1
Chief of Naval Research Washington, D.C. 20360	1
Commander, Naval Supply Systems Command (0421G) Department of the Navy Washington, D.C. 20376	1
Commander Naval Facilities Engineering Command Research and Development (Code 0322C) Department of the Navy Washington, D.C. 20390	1
Defense Documentation Center Cameron Station Alexandria, Virginia 22314	12
Civil Defense Research Project Oak Ridge National Laboratory P. O. Box X Oak Ridge, Tennessee 37830 Attention: Librarian	1
Dr. E. E. Massey Defense Research Board Ottawa, Canada	1
Professor Carl H. Koontz Department of Civil Engineering Worcester Polytechnic Institute Worcester, Massachusetts 01609	1
Dr. Robert G. Spicher Department of Civil Engineering San Jose State College San Jose, California 95114	1

DISTRIBUTION LIST (Continued)

Addresses:	Number of Copies
Professor John A. Samuel Department of Mechanical Engineering University of Florida Gainesville, Florida 32601	1
Professor Gale K. Vetter School of Architecture University of Colorado Boulder, Colorado 80302	1
Professor Richard E. Kummer 101 Eng. A Pennsylvania State University	1
Director Institute for Environmental Research Kansas State University ManHattan, Kansas 66502	1
Mr. Bert Greenglass Director, Office of Administration Program Planning and Control Department of Housing and Urban Development Washington, D.C. 20410	1
Commander, Naval Ship Systems Command Department of the Navy Washington, D.C. 20360 Attention: Code 03541	1
U.S. Naval Civil Engineering Laboratory Port Hueneme, California 93041 Attention: Librarian	1
Director, U.S. Army Engineering Waterways Experiment Station Post office Box 631 Vicksburg, Mississippi 39180 Attention: Document Library	1
National Aeronautics and Space Agency Office of Advanced Research and Technology 400 Maryland Avenue, D.C. Washington, D.C. 20546	1
Director, Defense Nuclear Agency Washington, D.C. 20301 Attention: Technical Library	1

DISTRIBUTION LIST (Continued)

Addresses:	Number of Copies
Dr. Rudolf J. Engelmann Division of Biomedical and Environmental Research U.S. Energy Research and Development Administration Washington, D.C. 20545	1
Dr. C. S. White President-Director Lovelace Foundation 5200 Gibson Boulevard, S.E. Albuquerque, New Mexico 87108	1
Mr. Donald A. Bettge Research Directorate Defense Civil Preparedness Agency Washington, D.C. 20301	1
Dr. Neil B. Hutcheon National Research Council Building Research Division Ottawa, Canada	1

RESEARCH TRIANGLE INSTITUTE, Research Triangle Park, North Carolina
Final Report RTI/1533/00/05F
DCPA Contract No. DCPA01-77-C-0232
Study of Crisis Utilization of Small Shelter Space
S. B. York, III and J. S. McKnight
August 1978 (UNCLASSIFIED) 102 pages

This study consisted of an investigation into the options available for utilizing small facilities such as local stores, churches, and schools for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary waste disposal systems for small groups of people. The emphasis of this study was on identifying differences in the characteristics of small facilities versus large facilities and determining the influence of these differences on the provision of services. In describing methods for augmenting and/or providing services, the interrelationships among the different systems in a facility were analyzed.

Also, an investigation was made of the relationships of group size and occupant density to the provision of services. Factors relating to the effects of group size and occupant density were examined and presented as an aid to the local planner in developing the shelter plan for a particular host area.

All of the analyses were made using existing data already collected.

Example problems illustrating the planning required to implement life-support systems are included as an appendix.

RESEARCH TRIANGLE INSTITUTE, Research Triangle Park, North Carolina
Final Report RTI/1533/00/05F
DCPA Contract No. DCPA01-77-C-0232
Study of Crisis Utilization of Small Shelter Space
S. B. York, III and J. S. McKnight
August 1978 (UNCLASSIFIED) 102 pages

This study consisted of an investigation into the options available for utilizing small facilities such as local stores, churches, and schools for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary waste disposal systems for small groups of people. The emphasis of this study was on identifying differences in the characteristics of small facilities versus large facilities and determining the influence of these differences on the provision of services. In describing methods for augmenting and/or providing services, the interrelationships among the different systems in a facility were analyzed.

Also, an investigation was made of the relationships of group size and occupant density to the provision of services. Factors relating to the effects of group size and occupant density were examined and presented as an aid to the local planner in developing the shelter plan for a particular host area.

All of the analyses were made using existing data already collected.

Example problems illustrating the planning required to implement life-support systems are included as an appendix.

RESEARCH TRIANGLE INSTITUTE, Research Triangle Park, North Carolina
Final Report RTI/1533/00/05F
DCPA Contract No. DCPA01-77-C-0232
Study of Crisis Utilization of Small Shelter Space
S. B. York, III and J. S. McKnight
August 1978 (UNCLASSIFIED) 102 pages

This study consisted of an investigation into the options available for utilizing small facilities such as local stores, churches, and schools for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary waste disposal systems for small groups of people. The emphasis of this study was on identifying differences in the characteristics of small facilities versus large facilities and determining the influence of these differences on the provision of services. In describing methods for augmenting and/or providing services, the interrelationships among the different systems in a facility were analyzed.

Also, an investigation was made of the relationships of group size and occupant density to the provision of services. Factors relating to the effects of group size and occupant density were examined and presented as an aid to the local planner in developing the shelter plan for a particular host area.

All of the analyses were made using existing data already collected.

Example problems illustrating the planning required to implement life-support systems are included as an appendix.

RESEARCH TRIANGLE INSTITUTE, Research Triangle Park, North Carolina
Final Report RTI/1533/00/05F
DCPA Contract No. DCPA01-77-C-0232
Study of Crisis Utilization of Small Shelter Space
S. B. York, III and J. S. McKnight
August 1978 (UNCLASSIFIED) 102 pages

This study consisted of an investigation into the options available for utilizing small facilities such as local stores, churches, and schools for nuclear fallout shelters in CRP host areas. Technical consideration was given to the provision of lighting, ventilation, water, and sanitary waste disposal systems for small groups of people. The emphasis of this study was on identifying differences in the characteristics of small facilities versus large facilities and determining the influence of these differences on the provision of services. In describing methods for augmenting and/or providing services, the interrelationships among the different systems in a facility were analyzed.

Also, an investigation was made of the relationships of group size and occupant density to the provision of services. Factors relating to the effects of group size and occupant density were examined and presented as an aid to the local planner in developing the shelter plan for a particular host area.

All of the analyses were made using existing data already collected.

Example problems illustrating the planning required to implement life-support systems are included as an appendix.